

BALLOON-BORNE AEROSOL COUNTER

by

Henry A. Miranda, Jr.

John Dolchinos

**GCA CORPORATION
GCA TECHNOLOGY DIVISION
Bedford, Massachusetts**

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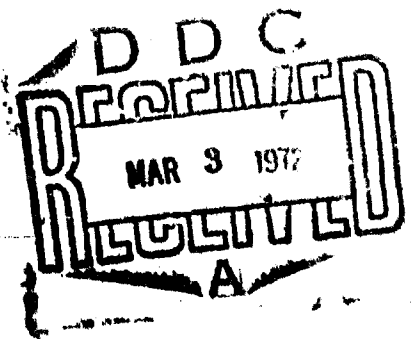
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Prepared for
**AIR FORCE CAMBRIDGE RESEARCH LABORATORIES
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UNITED STATES AIR FORCE
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A BALLOON-BORNE AEROSOL COUNTER

I. INTRODUCTION

This Final Report under Contract F19628-70-C-0265 describes the preparation for and successful test flight of a balloon-borne aerosol particle counter. The device samples individual particles and measures their sizes to an accuracy of ± 10 percent over an order of magnitude extending down to the 0.1 to 0.2 micron diameter regime. The size distribution of aerosols at various stratospheric altitudes during the ascent and descent portions of the balloon flight, as well as at float altitude, was measured successfully on the first balloon flight on 28 October 1970 at White Sands Missile Range. Preliminary results of this flight, which to our knowledge represent the first such data obtained to date, are presented here. This device was designed and fabricated under a previous program, Contract No. F19628-68-C-0086, but had sustained severe damage prior to its first flight test as a result of its accidental exposure to temperatures in excess of 200°C in an environmental test chamber. This necessitated the postponement of the originally scheduled field exercise, and the initiation of an extensive program of renovation and refurbishment.

A description of the aerosol counter, as well as a damage assessment report and recommendations for renovation has been presented in Reference 1. These recommendations, which included certain specific modifications to the electronics circuitry and especially to the ground support system, were implemented under the present contract, and are described subsequently in the present report.

Most of the mechanical and optical components were repaired under the prior contract in order to facilitate the damage assessment to the electronics circuitry. This was necessitated by the unique input requirements of the several digital modules involved. Hence, the renovation work performed under the present contract has been devoted largely to the electronics. During the course of this activity several additional modifications and improvements, which had not been contemplated originally, were incorporated for reasons which are discussed in greater detail herein.

For the benefit of the reader who may not have ready access to Reference 1, a brief synopsis of the counter system is presented in Section 2 of this report.

A thorough discussion of all renovation activity, including calibration and environmental testing, is presented in Section 3. With regard to calibration, it had been recognized that the scheme employed earlier, namely the use of Dow Corning "standard" polystyrene-latex spheres, though adequate in terms of providing a suitable range of particle sizes,

was nevertheless deficient in that only one index of refraction was available, namely 1.58. Under the present program, a technique was employed to generate particles of a known size with index of refraction equal to 1.50. This rendered it possible to test the capability of the aerosol counter to measure particle sizes accurately, (to within the prescribed 10 percent), over the anticipated range of particle index of refraction (1.33 to 1.50). The results obtained serve to strengthen one's confidence in this particular feature.

A description of the flight test activity is presented in Section 4. In addition, detailed discussions of both the rationale employed for the automatic processing of scientific data as well as a complete description of the manner in which this and other vital information is recorded on tape are also included.

The aerosol counter was flown on two successive balloon flights during a two week period in October 1970 at White Sands Missile Range. Excellent data were obtained on the first of these flights, while all data were lost on the second flight owing to a failure in the write circuitry for the tape recorder. Owing to the fact that the automatic data reduction procedures embodied in the existing computer program have not as yet been optimized, these data are considered as preliminary. In spite of this, however, this is believed to represent the most reliable and accurate source of information on stratospheric particle size distribution presently available.

II. BRIEF DESCRIPTION OF AEROSOL COUNTER SYSTEM

The aerosol counter operates on the principle of light scattering, and in this sense, is similar to other instruments of this kind. The novel feature of this instrument, however, is the introduction of a second optical light scattering channel which compensates for the strong dependence of scattering cross section on index of refraction, which is a common limitation of all known instruments. Straightforward solutions of the Mie scattering equations has shown that the ratio of scattered light at 30 and 10- degrees is essentially independent of the index of refraction over the range 1.3 to 1.55 for non-metallic spherical particles. Moreover, this ratio is directly proportional to the particle size (expressed in the form of the scattering parameter $\alpha = \pi d/\lambda$, where d is the particle diameter, and λ is the wavelength of light employed, in the appropriate units). This greatly relaxes the severity of assumptions which must be made in inferring particle size from light scattering data. Based upon this result, the device was designed to accommodate two separate annular scattering channels, viewing the scattered light in the 5 to 15-degree and 25 to 35-degree scattering directions, respectively.

Air is taken into the chamber by a specially-designed sampling system at a controlled rate, and is caused to flow in a laminar fashion through a small bore (1 mm diameter) tube, which is broken for a 3 mm

portion of its length. Orthogonal to the tube axis and through this broken portion, is directed an intense beam (15mW) of highly collimated light at 6328\AA from a Helium-neon gas laser. The collimation feature is most important since it allows a maximum of illumination of the 1 mm interaction volume, while at the same time maintaining the angle of incidence of all the light near zero degrees. The laser is maintained within a pressurized housing to minimize overheating and to prevent high-voltage arcing at the reduced ambient pressures encountered during balloon flight.

Light scattered by the particles within the interaction volume is collimated by two annular systems: (1) a lens for the 10-degree light, and (2) an off-axis paraboloid-of-revolution mirror for the 30-degree light. The two collimated beams are directed to each of two PM detectors by a set of two 45-degree plane mirrors mounted in a central housing. The detector together with associated condensing lenses and image apertures, are housed in two lateral arms. The image apertures are carefully adjusted to allow only the scattered light from the interaction volume to strike the PM detectors. Light scattered from such solid surfaces as the end of the flow tubes is thereby strongly attenuated.

Unused light from the laser beam passes on through axially, and is absorbed by a Wood's horn which reduces the back scattered laser light in the vicinity of the interaction volume to acceptable levels. Since the system sensitivity is limited by noise associated with Rayleigh scattered light by ambient air molecules within the small interaction volume, all other sources of laser light in the vicinity of this region must be reduced to one part in 10^{11} which is accomplished by the Wood's horn arrangement.

The flow speed is maintained constant throughout the flight by means of a critical orifice, such that the dwell times of particles crossing the laser beam in the sensing gap is about 250 microseconds. Hence, pulses of this duration are generated at each of the two PM detectors, whose peak values are proportional to the respective scattered light intensity in each of the two (10 and 30-degree) scattering channels. The data from both channels are digitized and recorded on a Kinelogic 9 channel tape recorder in a format compatible with a IBM 360 computer. A dynamic range of four orders of magnitude is accommodated by the circuitry. In addition, several important housekeeping functions are also sampled periodically, and recorded on tape in digitized form. Included here are PM high voltage, laser output power, air flow rate, altitude, temperature, and other parameters.

The signal processing electronics include pulse peak detection circuitry, clock and timing circuits, (which generate the basic timing waveforms for the entire system), read-in control circuits, (which control the flow of information traffic through the sequence of complex signal

processing operations being performed therein), A/D circuitry, (which includes a unique logarithmic/linear function to handle the large dynamic range of certain signals), and magnetic tape recording circuitry (which provides an output compatible with the IBM 360 system, including parity, CRC and LRC generators).

A computer program has been generated to reduce the raw data and present the results in the form of a size distribution, together with the total number of particles being counted.

III. PREPARATION FOR FIELD MEASUREMENTS

The major effort under the current contract was devoted both to the repair and renovation of damaged modules and the fabrication of certain new circuits designed under the previous contract. During the course of this work, it was found appropriate to modify several additional modules not originally contemplated. As part of this activity, the equipment was subjected to a full flight simulation test at the AVCO Environmental Test Facility at Wilmington, Massachusetts.

Upon completion of these renovations and modifications, the equipment was calibrated with a broader range of particle sizes than had been employed previously. A test with particles having a different index of refraction was also performed which demonstrated that the equipment is much more insensitive to index of refraction than single-channel devices.

A. RENOVATION, MODIFICATIONS AND ENVIRONMENTAL TESTING

With regard to renovation, a somewhat unusual procedure was developed as a result of the rather unique circumstances encountered in the present situation. Although all the circuit boards had been discolored (which suggested severe deterioration as a consequence of the test chamber accident discussed previously), more detailed testing of selected circuits indicated that operating specifications might not have been compromised to as serious an extent as had originally been supposed. As a consequence, it was decided to subject all circuit boards to the wash, rinse, and dry cycle of an automatic washer and thereby challenge each element severally. A detailed microscopic inspection of each component and connection was then performed, and repairs and/or replacements were executed as required. This was followed by the usual testing and checkout procedure, including environmental tests, and rework if necessary, etc. This procedure was predicated on the judgment that the resulting probability of component failures would not be greater than that associated with the installation of new, unchallenged, components.

The following subsections describe in greater detail the work performed on specific items.

1. Power Supply Renovation

a. Low Voltage and Laser Supplies

These two modules provide power for operating the electronic processing circuitry and laser plasma tube, respectively, and were designed and operated originally as two separate units. The low-voltage supply was restored to operation, but an adequate assessment of its reliability would have involved a greater expense than that required to rebuild the unit completely. With regard to the laser power supply, a means was found to greatly simplify its design and hence improve its reliability. In the course of implementing these modifications it was decided to combine these two modules into a single dual unit. One portion provided a 22 kHz 400V P-P, square wave voltage to drive the laser plasma tube. This was current limited at the desired load level to control the plasma tube current. The other portion provided several separate outputs for the following modules:

6.3V	3.5 amps	-	pump motor
+17V	-17V	-	electronic circuitry
+28V	(regulated)	-	tape recorder and HV power supply

b. High Voltage Power Supply Renovation

Preliminary damage inspection and testing of this module indicated that renovation could be accomplished by simply replacing all high voltage capacitors. However, when renovation was initiated, several more subtle aspects of damage were brought into clearer focus. Among these was deterioration of both the circuit board etched wiring and the potting compound, as well as the possibility of latent damage in the high voltage transformer and high voltage rectifier. This unit, procured originally from a separate vendor as a completely encapsulated commercial unit, had been modified previously to provide short-circuit protection, and also to add additional filtering. This latter feature had been incorporated externally to avoid the extensive repackaging that would have been required, which at the time was precluded by the existing scheduling constraints. Although it was recognized that repackaging would have been desirable owing to the geometrical constraints peculiar to this particular application, it was nevertheless not essential, and therefore, had been judged to be of secondary importance under the conditions of exigency which prevailed. However, such was not the case when the present work was initiated. The need to perform extensive repairs rendered it a relatively simple matter to repack the high voltage supply with the added filtering and the short circuit protecting features provided as an integral part of the supply.

The high voltage power supply was completed and tested thoroughly in the AVCO Environmental Test Facility, since output stability

was an important consideration, particularly with regard to temperature environment. The results of these tests showed that over a temperature span of -30°F to $+150^{\circ}\text{F}$, the temperature coefficient of the output voltage of the supply was well within acceptable limits averaging approximately -0.015 percent/ $^{\circ}\text{F}$.

2. Tape Recorder Renovation

The tape recorder refurbishment effort included the replacement of four of the mylar drive belts and the replacement of the inverter module. Electrical and mechanical tests had been performed on the tape recorder at an earlier date to establish the areas requiring rework. Tests on the record head indicated virtually no performance degradation. The motor, on the other hand, showed a significant increase in bearing friction. New bearings were therefore obtained and installed. In order to provide backup support for the field operation, however, a new motor was procured as part of the spare parts inventory. During the final checkout, it was noticed that a failure had occurred in one of the buffer amplifiers which constitute a portion of the input circuitry of the tape recorder unit. These modules were found to be redundant since the output commands of the aerosol counter electronics had been designed to be compatible with the tape recorder input requirements. Therefore, rather than replace the defective amplifier, it was decided to modify the tape recorder circuitry so that the output commands would be applied to the tape recorder inverter directly. This modification eliminated three superfluous buffer amplifiers and hence provided improved system reliability.

In addition to the components discussed above, an internal $+5\text{V}$ power supply is incorporated within the tape recorder module, which constitutes the only major electronic module therein. Since this supply showed no degradation in performance and is very lightly loaded with respect to its output current capabilities, it was concluded that a replacement of this module would be unwarranted.

3. Ground Support Equipment

A rudimentary ground support unit had been fabricated previously to facilitate testing and checkout of the electronic circuitry for use during the first scheduled field exercises. This consisted of a small control console that permitted the following operations:

- (1) use of either internal (i.e. battery) or external power for the entire aerosol counter
- (2) selective operation of the tape recorder (on/off, fast/slow, forward/reverse, and read/write)
- (3) meter monitoring of each of the various power supply outputs

- (4) Monitoring of all housekeeping parameters at an accelerated sampling rate to permit viewing on an oscilloscope, or at the normal rate. (During normal operation, these parameters are sampled, processed and recorded once every 20 seconds, which is an inconvenient sampling rate for most monitoring purposes.)
- (5) Activation of special confidence check circuitry built into the aerosol counter. (This consists of a small pulsed light source to simulate the scattered light from the particles observed by the PM tubes, which constitutes the basic datum of scientific import.)
- (6) Oscilloscope monitoring of the digital data. (This is sampled at the input to the record electronics module, where it is available in serial form.) Appropriate signals are also monitored which permit synchronization of the oscilloscope trace to facilitate viewing of the digital information.

As part of the damage evaluation and preliminary refurbishment activity under the prior contract, an improved ground checkout device was designed which incorporated all of the above features, together with a digital-to-analogue converter and associated logic circuitry which permitted the monitoring of the output of the record electronics in the form in which the information is impressed on the tape recorder (i.e., parallel format), and (2) provision for monitoring all housekeeping functions in analog form before digitalization. These combined functions allow a comprehensive check to be performed on the entire digital data processing circuitry. Additional features include a parity check, as well as provisions for feeding out several other synchronization pulses to facilitate oscilloscope monitoring.

Under the present program, the above-described unit was fabricated, tested, and operated in the field exercises with entirely satisfactory results.

In its present state of development, the ground support unit lacks only one feature, namely the ability to check out the data following impression on the magnetic tape. Scheduling and funding limitations precluded the incorporation of this feature under this present contract, but it is recommended that this be considered for future work.

During the course of this activity, the desirability of having a battery charger which would be provided as an integral part of the ground support equipment was recognized. Although the batteries could have been charged externally, this would have resulted in the

inconvenience of either: (1) the removal of the battery pack to the battery charger facility, or (2) the provision of a separate auxilliary power supply which would be connected to the ground station equipment by an external cable. In order to provide the degree of operational flexibility required for ground checkout during a field operation, a simple battery charger circuit was built and incorporated into the system as an integral portion of the ground support equipment.

4. Miscellaneous Items

a. Elimination of Spurious Pulses in CRC Generator

Detailed visual inspection of each circuit module of the refurbished portions of the aerosol counter was performed in accordance with the program plan. After the environmental test had been performed at the AVCO Test Facility, it was discovered that the CRC generator had been operating intermittently. This was traced to electrical ringing at the trailing edge of the shift pulse for the CRC circuitry, and was eliminated by adding appropriate additional filtering.

b. Improvements in Confidence Test Circuitry

As a result of the use of an AC drive signal in place of the original DC power input to the laser exciter, the requisite +150V source of power was no longer available for the neon lamp light sources in confidence test circuitry for the aerosol counter. Rather than design a special power supply for these lamps, the confidence test circuitry was modified to work with light emitting diodes (LED), which operate with low voltages. These have been available commercially only recently and, unlike the neon bulbs previously used, do not exhibit a "dark effect". This has resulted in improved system reliability.

c. Peak Detection Circuits

The two photomultiplier preamplifier modules, using the new peak detection circuitry designed under the previous contract, were constructed and tested. This design supplants the older concept, in which that portion of each PM output pulse protruding above a fixed threshold level (determined by the noise level) was integrated as a measure of the scattered light received in each channel. This scheme had been incorporated in the original design to suppress inaccuracies arising from noise fluctuations superposed upon the pulses. However, in practice this was not found to be a significant source of error, so that the associated disadvantage (namely the introduction of inaccuracies associated with the time delay of the initiation of a pulse emerging out of the threshold level), no longer warranted the use of this scheme. This difficulty, which becomes more serious the smaller the particle being observed, has been alleviated in the present peak detection design, since its output is much less affected by pulse initiation time delays.

d. Time Code Generator

The overall system as previously constituted was found to be somewhat deficient with regard to the association of particle size data with balloon altitude data. Although the requisite information was available on the tape record, it was found to be in a form which was inconvenient for ready data processing. Hence to facilitate the data reduction procedure, a time code generator was designed, fabricated and incorporated into the electronic circuitry. This module generates the elapsed time in hours and minutes from an appropriate reference time (e.g., launch) and records this information. Two vacant tape character positions, which had previously been made available on a contingency basis for recording housekeeping parameters which might be found necessary, were employed for this purpose.

In this connection, it should be noted that correlation of balloon height profile data between the three separate sources (namely, aerosol counter altimeter, balloon control system altimeter, and radar returns), exhibits need for improvement. Since these discrepancies can be traced to timing inaccuracies and the establishment of the initial reference time between the separate timing systems, it is recommended that a suitable crystal-controlled oscillator be installed in the aerosol counter as the clock reference of the time code generator, and that a more positive means be instituted for establishing an initial reference time for each flight. Timing precisions to within a few seconds is considered to be sufficient for most balloon flight experiments. It is of course also necessary to insure that similar precision is available on the other systems.

e. Additional Temperature Probes

The possibility of overheating during a daytime balloon flight was considered. As a precautionary measure, the gondola was covered with specially treated aluminum panels*. These panels are coated with a material having increased emissivity in the IR, to reduce the sun load. Nevertheless, sufficient uncertainty remained regarding the predicted temperature history of such critical components, e.g., for instance, the laser housing, power supplies, etc., to warrant the use of additional temperature monitors wherever possible. The deletion of the corona altimeter created a vacancy in one of the tape character positions in the recorded format of housekeeping data. This permitted the inclusion of a separate temperature sensor, for which the appropriate encoding circuitry was constructed and installed.

* Finished by ALZAK process, Alcoa Aluminum Corporation.

f. Housekeeping Monitor Outputs

The analog housekeeping circuitry used in the original system were contained in three circuit boards. These were replaced by three new circuit boards in which the design has been modified to provide external analog outputs in parallel form. Thus, continuous housekeeping data are available for monitoring the input to the A/D converter. This is an important adjunct to the ground support checkout system.

g. Air Pump

A new air sampling pump was obtained and installed to replace the pump in the original system as a precautionary measure against the possibility that its life might have been shortened as a result of the exposure to high temperature.

5. Environmental Testing

As part of the general refurbishing effort, extensive tests were performed on the electronics portion of the aerosol counter, using the small GCA test chamber. Temperature tests with equipment operating covered the range from -30°F to $+150^{\circ}\text{F}$. The equipment was exposed to several cycles of temperature stress, which served the useful purpose of identifying not only marginal components, but also several minor circuit weaknesses which might otherwise not have been detected.

Full-scale environmental tests of the complete aerosol counter system were then conducted at the AVCO Test Facility in Wilmington, Massachusetts. These tests revealed two circuit design deficiencies requiring relatively minor modifications: an incorrect scale factor in the altitude housekeeping circuitry, and ringing in the CRC generator. Corrective measures to the former involved changing a resistor, while those pertaining to the latter involved the addition of a suitable filtering network, which has already been discussed in Subsection 4a above. Appropriate bench tests were conducted upon completion of these modifications, since these were judged not to be extensive enough to warrant repetition of the full-scale environmental tests.

The optics subassembly was installed in the balloon gondola and checked out completely. The alignment of the laser and the 10 and 30 degree optics was tested and adjusted for optimum performance. The laser and high-voltage photomultiplier housings were leak tested and found to be pressure tight. The sampling chamber was found to have several small leaks which were repaired.

The photomultipliers and laser were tested in an environmental temperature chamber over the range -15°F to $+100^{\circ}\text{F}$ and were found to perform satisfactorily. Sensitivity changes were similar for the two

tubes and the overall change was only ~ 10 percent, which is tolerable. The photomultipliers exhibited less than 5 percent hysteresis in sensitivity, and this exhibited partial recovery after an overnight period. It is felt that full recovery would be realized over a correspondingly longer time period.

6. Air Sampling Flow Rate

The system was designed to accommodate static air sampling rates of 3 to 5 cm^3/sec . This range is associated with several equipment parameters, the dominant one being the dwell time of a particle in the airflow sensing gap as it crosses the orthogonal laser beam (~ 1 mm diam). This represented a compromise in the complex trade-off considerations between large sampling rates (to increase the counting statistics for the expected low aerosol concentrations at balloon altitudes), a small diameter flow tube (to decrease the probability of more than one particle being illuminated by the laser beam simultaneously), and a slow flow speed (to reduce the signal processing electrical bandpass and thereby improve signal-to-noise ratio for small particle detection). On this basis, the electrical bandpass was chosen, and the circuitry designed accordingly to accept pulses of about $1/4$ millisecond minimum duration. The flow rate was set at the lower end of this range to favor somewhat the sensitivity of the instrument to small particles at the expense of higher confidence statistics.

At this point, a complicating feature of the sampling system should be pointed out. Due to the necessity of avoiding any windows in the path of the laser beam, (which would result in unacceptably high background light levels owing to surface scattering effects) the sensing gap (~ 1 mm³) communicates with a much larger volume (~ 7 liters), which is sealed from the surrounding air to ensure that all the air taken in through the inlet tube indeed passes through the sensing gap. This volume is comprised of the sampling chamber as well as the adjacent laser baffling chamber, of which the latter is by far the larger contributor.

As the balloon rises through the exponentially decreasing atmospheric density, the air in this chamber must be evacuated, and can only exit through the sensing gap. Since the total volume flow rate of air exiting from the system is controlled by a critical orifice, and is therefore constant, the air sampling rate will be diminished by the chamber evacuation rate.

Selection of the original flow parameters was predicated on a balloon rise rate of 100 meters/minute, and an evacuation volume of about 1 liter. On this basis, calculations indicated (Ref.2) an anticipated maximum evacuation flow rate of $0.23 \text{ cm}^3/\text{sec}$ which was less than 10 percent of the static air sampling rate, and hence easily tolerable. However, the estimates of balloon rise rates and evacuation volume were

found subsequently to be optimistic by a considerable margin. More realistic flight profiles indicated that balloon rise rates would likely reach 200 meters/minute during certain portions of the flight. In addition, the laser baffle design which finally emerged was much more voluminous than originally anticipated, resulting in an evacuation volume of 7 liters. The combined effect of these two parameters was to increase the peak evacuation flow rate to $3.2 \text{ cm}^3/\text{sec}$.

To reduce the possibility of negative sampling flow (i.e., net outflow through the intake port), the static air sampling rate was increased to $5 \text{ cm}^3/\text{sec}$. This was achieved by simply increasing the diameter of the critical orifice, (the pump having a sufficient capacity to maintain the necessary pressure drop across the constriction under the increased flow rate to assure Mach 1 conditions therein). In addition, the differential pressure-flow transducer was recalibrated to incorporate the higher total flow rates expected during descent, which result from filling flow being added to the static air sampling rate.

In spite of this increased value, the actual balloon flight profile was such that negative sampling flows were experienced on several occasions during balloon rise. These portions of the data were simply ignored. It should be noted in this connection that the particle counting statistics for the descent portion of the balloon flight are much more favorable than those for the rise portion, owing to the increased total sampling flow under these conditions. This is somewhat fortuitous, in that the descent portion data are less subject to the possible disturbing influence of balloon contamination and hence are likely to be more reliable by virtue of this fact alone.

B. CALIBRATION

As noted previously, the calibration activity included two separate particle generation schemes. The main technique involved the use of a suitable nebulizer and highly dilute suspensions of commercially available monodisperse polystyrene-latex spheres. This technique had been employed previously using two particles sizes: 0.557 micron and 0.796 micron and is described in Reference 1. In the present instance, seven different sizes were procured (Refs. 3,4) and utilized: 0.198, 0.312, 0.365, 0.500, 0.557, 0.796, and 1.099 micron diameter. These particles were introduced sequentially into the aerosol counter, and all data were processed initially as though these sizes were unknowns using an assumed calibration constant. The output for each particles size was then compared with the known values, and a corrected average value calibration constant was thereby obtained. This was reinserted into the computer program in iterative fashion to converge to the final value*. The resulting size distribution plots obtained from these final computer runs showed sharply defined peaks, each within ± 10 percent of the respective values of particle sizes noted above.

* As will be discussed in the next subsection, a different numerical calibration constant applies for particles with $\alpha < 2$ (i.e. diam < 0.428), since the absolute value of scattered intensity (as opposed to the ratio), is utilized in this range of particle sizes.

The polystyrene-latex particles employed in this calibration scheme have an index of refraction of 1.58, whereas the aerosol counter was intended for use in the stratosphere where the particle index of refraction is more likely to be in the range 1.33 to 1.50. It should be noted that the principle upon which the instrument design was predicated, (and upon which the interpretation of results is based) embodies the assertion that the output is not affected by the index of refraction over this range, which rests on sound theoretical reasoning. Nevertheless, a test of this hypothesis was judged to be highly desirable. Hence, an alternative scheme was devised to provide particles with a different index of refraction than that exhibited by the easily available polystyrene-latex spheres.

For this purpose, aerosols were generated using DOP (dioctyl phthalate), a liquid of low vapor pressure, in combination with a condensation type aerosol generator (Refs. 5,6). The limited scope of this particular effort permitted the generation of only one size of particles for insertion in the aerosol counter. The average diameter was measured with a specially-constructed "owl" device, a recent version of which is described in Reference 5. The principle involved in this measurement is the observation of the scattering angle at which the first red band of the Tyndall spectrum appears. Kitani (Ref. 7) describes this method in detail and shows that over the range of indices of refraction between 1.33 and 1.55, the relationship between particle radius, r and the scattering angle, θ (from the forward direction) at which the first red band appears is given by:

$$\log(\theta/10) + 1.43 \log(10r) = 1.43$$

Liu (Ref. 5) modified this equation and obtained a more explicit form:

$$D_p = 10\theta^{-0.7}$$

where D_p is the particle diameter. DOP particles have an index of refraction of 1.49 (Ref. 5) and are therefore well suited for this purpose.

A single particle size run of 27-minute duration was conducted using this scheme. The undiluted output of the evaporation-condensation generator was made to flow through the "owl" for size measurement, which was found to be typically 0.9 micron. A small fraction of the concentrated aerosol stream from the generator was diluted by several orders of magnitude with a clear air stream so that the concentration entering the aerosol counter would be sufficiently small to preclude the simultaneous illumination of more than one particle by the laser beam.

The digital output of the aerosol counter as recorded on magnetic tape was processed using the same procedure as would be employed for the actual balloon flight data. The results were shown to be in good agreement with the measurements obtained using the "owl" apparatus. Thus, it can be asserted with reasonable assurance that the particle sizing accuracy of the aerosol counter is within ± 10 percent over the 1.33 to 1.50 index of refraction range.

Finally, it should be noted that, in the case of the polystyrene spheres, the smallest particles tested, namely 0.198 micron, were processed without difficulty. From visual observation of the PM preamplifier outputs of one of the two scattered light channels, the pulses observed were well above the average noise level. This would imply that the system should be able to approach a 0.1-micron capability, at least under the controlled conditions prevalent in the laboratory.

While admittedly this is a rather poorly defined criterion upon which to extrapolate system behavior, it nevertheless represents the best information presently available. This assertion seemingly conflicts with conclusions drawn from the actual flight data, as will be discussed below. However, it should be noted that: (1) these data represent the only field experience with this equipment to date, (2) the operating conditions probably deviated considerably from those prevailing in the laboratory, and most importantly, (3) certain data processing difficulties have been revealed by this first experience, which still remain to be rectified. It is therefore anticipated that some improvement in system size sensitivity can be achieved, which will narrow the gap between these seemingly conflicting conclusions. Specific recommendations for modification of the computer processing procedures in pursuit of this goal are discussed in the last section of this report.

C. COMPUTER PROGRAM MODIFICATIONS

The program in its original form contained an averaging procedure which selected a prescribed set of altitude increments from the housekeeping data and processed these to derive average value size distributions for each altitude increment. Early in the contract, consideration was given to the effect of likely deviations in balloon-rise flight profile from that upon which the original averaging procedure was predicated. For a smooth rise profile, automatic computer processing can be achieved by relatively simple means. However, in the presence of significant departures from the smooth rise case, automatic processing of the data would require the introduction of elaborate look-ahead and smoothing procedures, involving not only extensive revision of the computer codes, but also other undesirable complexities such as extra data tapes for temporary data storage, and much longer processing times, etc.

Upon consultation with the project technical monitor, it was decided to modify the averaging procedure whereby time (or its equivalent, namely record number) is used as the independent variable. This has resulted in some simplification of the computer program. However, it is no longer completely automatic, in that the averaging time intervals must be inserted externally after examining the actual flight profile. This involves a slight inconvenience, namely that the processing cannot proceed until this input information has been made available. However, based upon limited experience so far, this does not seem to constitute a serious problem.

Two additional modifications were introduced as a result of the early experience gained upon initial processing of the actual flight data. The first of these modifications was occasioned by the rapid changes in balloon ascent rate experienced on the first balloon flight, which is reflected in unexpectedly low flow rates in the particle sensing gap. As a result, the particle size distribution determination is rendered unreliable owing to the possibility of a single particle being counted several times in successive sampling intervals. In addition, the total particle count in these instances is subject to large statistical uncertainties owing to the small number of counts involved. This is also aggravated by the fact that the total time duration for a given altitude increment is reduced with increasing rise rate. For these reasons the program was modified to ignore all records with small (or negative) flow rates.

The second of these modifications was concerned with that portion of the program which yields the total concentration. Since in this case the larger number of counts involved result in smaller statistical uncertainties, it was possible to modify the program to enable the total particle concentration to be extracted from a smaller number of records. This permitted these particular data to be presented on a finer altitude grid.

The implementation of this latter modification introduced a minor problem, namely that record counting is upset if the final record which is processed in this particular manner for a given altitude increment, happens to be a record with low or negative flow rate. This problem is a direct consequence of the fact that these latter records are now ignored by virtue of the previous modification discussed above. This was not recognized as such until after the data processing had been completed. Since it was not possible to make the necessary adjustments prior to the completion of work under the present contract, this problem remains to be rectified.

IV. FLIGHT TESTS

A. FIELD EXERCISES

The field operation is discussed in somewhat greater detail than would ordinarily be the case for a report of this kind, owing to the fact that this represents the initial field experience with the system.

The instrument was shipped by air to Holloman Air Force Base, and checked out for a second series of environmental tests, which included an altitude run (i.e. without temperature variation) on 15 October 1970, and a complete altitude/temperature simulation profile on 16 October. During the course of the latter test, for reasons beyond our control, the instrument was placed accidentally in direct contact with the refrigeration coils of the chamber, so that the low temperature exposure was far more severe than anticipated in the system design. In spite of this, the equipment performed satisfactorily, with the exception of one housekeeping unit, namely the elapsed time indicator which was repaired subsequently.

On 19 October the equipment was shipped to the Stallion Site of the White Sands Missile Range for prelaunch readiness operations, which were performed during the ensuing week. One major problem area remained to be investigated, namely, the possibility of thermal danger to the equipment resulting from the simultaneous effects of internal power dissipation and external sun load at high altitudes, where heat transfer by conduction to the atmosphere would be diminished significantly by virtue of the reduced ambient pressure. Owing to the short time available, the investigation was limited to a determination of the relative absorptivity of various coatings and materials that could conceivably be used to replace the specially-coated aluminum sheets discussed previously.

Several different samples were exposed to direct sunlight on a relatively calm day. The temperature rise of each sample was recorded after the temperature had attained a stable value. The samples included a panel of the type used to cover the aerosol counter gondola, an aluminum panel which was painted with a white titanium dioxide paint, and an aluminum panel which had been iridized. The temperature rise of the gondola panel was measured for both the shiny surface and the dull surface. The test results showed that the lowest temperature rise was experienced by the gondola panel for the shiny side. The next lowest temperature rise corresponded to the gondola panel on the dull side. The temperature rise of the white panel was significantly greater than the temperature rise of the gondola panel even when compared to the dull side. The temperature rise of the iridized aluminum panel was the greatest.

Because of both the relatively crude nature of the experiment, and other factors such as variations caused by occasional gusts of wind and the lack of appropriate thermal measuring instrumentation, it was not possible to quantitatively determine the absorptivities and the emissivities of the samples to a useful degree of accuracy. Nevertheless, the tests served to corroborate that the panels which had already been installed on the gondola were the most appropriate for minimizing temperature rise therein. Although it was indicated that slightly better results would have been obtained had the panels been installed with the shiny side facing outward, it was felt that the difficulties involved in inverting the panels would not be worth the relatively small improvement to be attained thereby.

During the course of this investigation, an opportunity was presented for the first time to operate the entire system continuously for several hours under full solar illumination. At the end of this period, it was noted that laser power had decreased significantly and that the laser temperature had reached 65°C. It is believed that previously, this temperature had never exceeded 55°C. Inspection of the laser and subsequent tests indicated that the laser power loss was due to optical misalignments which appeared to be a function of both temperature and operating time. Further investigation disclosed that the mirrors of the laser are joined to the laser tube by means of metal bellows. These bellows act as a shield against dust deposits on the mirrors and Brewster windows of the laser tube, and hence, are relatively air tight. The laser as packaged in the aerosol counter is sealed in a tube which is maintained internally at local atmospheric pressure. As the laser temperature increases, the air volume inside the tube is heated and the pressure therein is increased enough that, by virtue of the bellows arrangement and the nature of the mirror mount design, a misalignment develops. To correct this problem, the laser housing was fitted with a pressure valve and gauge to allow selection of an optimal operating pressure just prior to flight. The gauge also provides an extra assurance that the seal of the laser tube has no leaks. Such a gauge would be desirable in the high voltage section which also is maintained at atmospheric pressure.

On the morning of 28 October 1970, the aerosol counter was ready for its initial balloon flight test. At 7:02 AM the package was launched from the runway at the Stallion Site of White Sands Missile Range. The programmed flight profile consisted of an ascent phase which lasted 2-3/4 hours. This was followed by a float phase at an altitude of about 80,000 feet for a time interval of about 20 minutes. During the final three hours of flight, the balloon descended slowly to about 50,000 feet at which point a telemetered ground command caused the balloon to be separated from the aerosol counter and destroyed. The experimental package was then returned to earth by parachute.

Unfortunately, the flight lasted somewhat longer than the automatic turn off time of 6 hours, so that no data were collected during the latter portion of the descent phase (below about 16 km).

The gondola landed in flat grazing terrain, in an upright position. Impact was nearly vertical although the crush pads indicated some horizontal component. A limited on-site inspection indicated that the equipment had probably operated as planned, and data had been obtained. The tape recorder was removed and a dump of the data was obtained at the White Sands Missile Range on the following day. It was intended originally that the data would also be processed at White Sands; however, the center computer facility personnel had not had time to program the necessary input and format statements. A limited manual data reduction was performed and the following information was obtained:

- (1) The balloon trajectory contained many points at which rapid changes in rate of rise occurred. Furthermore, the rate of rise at many points was considerably higher than the scheduled 600 feet per minute value. Because of these two undesirable factors, the fluctuations in flow rate into the sampling volume were often quite severe. In fact, at several points just before float altitude was reached the input sampling rate dropped to zero.
- (2) A count was made of the number of particles which were present in several representative records on the magnetic tape record. A crude computation was then performed to obtain a particle density figure at several altitudes in units of particles per cubic centimeter. The values thus obtained appeared to agree with the currently accepted estimates.
- (3) Housekeeping data appeared to be normal except for the elapsed time output.
- (4) Laser power remained relatively stable during the flight.
- (5) A relatively large number of parity errors were indicated by the computer printout. These could result either from excessive dust on the magnetic tape or in an intermittent noise susceptibility in the equipment. It is also quite possible that noise introduced by the power supply inverter could have caused some of the errors.
- (6) On at least two files of data the computer printout indicated that no end-of-file mark was found in the recording.

The equipment difficulties listed in Items 3 and 6 above are relatively minor and have virtually no effect on the quality of the data collected. Item 5 on the other hand could result in the loss of all data in several records. However, this is not a particularly serious circumstance, since only about 30 percent of the records are thus affected, and of these only a small fraction will be discarded in fact.

In this connection it should be noted that the total number of successful sampling intervals recorded during the six hour flight, from which useful data can be extracted, exceed 10^6 . Thus, despite these few minor equipment and operational problems noted above, the first balloon flight of 28 October was highly successful. The data have been processed in a preliminary fashion and the results are presented in Subsection C below.

On the morning of 30 October, the aerosol counter was returned to the Stallion Site and checkout preparation for the second balloon flight was commenced. The equipment was found to be operating within specifications except for (1) the end-of-file circuit and the readout portion of the housekeeping circuit which is used to generate elapsed time, (2) spurious pulses at the frequency of the power supply inverter which appeared on several command leads to the tape recorder electronics circuitry, and (3) the output voltage of the 5V supply for the integrated circuitry, which was below the minimum acceptable level. The spurious pulses were eliminated by the addition of appropriate by-pass capacitors, and the output of the 5V supply was adjusted to the appropriate level. The combination of these two corrective measures resulted in the elimination of the end-of-file circuit difficulty.

During the remaining days prior to launch, several additional equipment difficulties were brought to light, among which were included: a cracked battery cell, laser power supply transformer failure, and a leak in the high voltage pressurized compartment. The necessary repairs were all executed, and the entire system was readied for launch at 7:30 AM on 3 November 1970.

As in the case of the first flight, the experiment package was recovered with no apparent damage. The position of tape in the tape recorder indicated that the pre-programmed 6-hour operating schedule had taken place. However, when a computer playback was attempted on the following day, it was discovered that the portion of the tape which corresponded to the flight was blank. The only data on the tape corresponded to the initial preflight test activity, which had been obtained in the balloon building at about 3:00 AM on the day of the flight. Hence, the failure must have occurred between final checkout and the commencement of actual in-flight recording.

The cause of the failure to record has not yet been identified positively. The most probable cause appears to be the loss in dc power in the record portion of the tape recorder electronics circuitry. Subsequent tests indicate that the system is recording properly. This points to an intermittent problem which must be investigated and corrected prior to future field test applications.

B. DATA PROCESSING

1. Introduction

As noted previously, it has not been possible to develop optimum data reduction procedures within the limited time and funding available under the present contract. Thus, the results to be presented in this report are considered as preliminary, pending the outcome of several experimental computer runs which remain to be performed. It is anticipated that these data processing improvements will be reflected in the realization of the full potential of this instrument, namely the attainment of 0.1 to 0.2 micron diameter capability.

A description of the manner in which the information is sampled and recorded on tape is given first, together with pertinent comments and several necessary input relationships for the data reduction computer program.

Also discussed is the method by which background levels are sampled and presented, as well as low laser power, "dead" time corrections, and temperature corrections, are to be applied.

This is followed by a section describing the rationale upon which the automatic computer processing of the scientific data is based.

2. Data Reduction Input Considerations

a. Tape Format

The recordings prepared by the aerosol counter circuitry consist of a series of data groups called records, which are separated by blank areas of approximately 0.6 inch in length. A pictorial representation of a typical data record is shown in Figure 1. Eight separate tracks (labelled 0-7 but not in numerical sequence) are used for recording data, while the ninth track (labelled P) is used for a parity bit. As can be seen from the figure, the recording begins with a 16 character unique code followed by 16 characters representing housekeeping functions. At the end of the first 32 characters the recording system automatically switches from a housekeeping mode to a data mode. Thus the remaining 3488 characters are employed for data recording. Since two characters are required for each data sample (10⁰ PM output and 30⁰ PM output), a total of 1744 samples can be stored in each record.

- (1) The first eight characters, which are recorded in positions, (or bytes) 0 through 7 of a record contain the binary representation of 255 (all bits are "1's"). The parity bit is a one because odd parity is used.

- (2) The following eight characters (positions 8 through 15 on the tape) represent 0 in binary form so that the parity bit for these characters is a one.
- (3) The 17th character (position 16) through the 30th character (position 29) contain housekeeping parameters in straight binary form. The system normalization is such that all zeros represent zero volts and all "1's" represent:

$$5V \times (1 - \frac{1}{256}) = 4.980 \text{ volts}$$

Thus, the voltage representation is

$$E_H = \frac{5}{256} \times A_B$$

where A_B is the binary character stored on the tape. The voltage representation E_H for each housekeeping parameter can be translated to the actual parameter using the scale factors and calibration referenced in Table 1.

- (4) The characters in positions 30 and 31 represent binary time in hours and minutes respectively.
- (5) The characters which are present in positions 32 through position 3519 represent samples recorded during the data mode interval. The 32nd and 33rd positions contain the first data sample. The even numbered positions from this point represent the output of the photomultiplier at the 10 degree scattering angle while the odd numbered positions represent the PM output at 30 degrees. In this sample and in subsequent data samples the character positions are such that if N represents the character position on tape of the 10 degree sample, the position of the corresponding 30 degree channel will be at $N + 1$ (never at $N - 1$). During the data mode, the binary number in each character position is related to the output of its corresponding photomultiplier output as follows:

$$I_p = 10^{-8} \times 10 \exp \left(\frac{2 A_B + 1}{128} \right) \times (1 \pm 0.0183)$$

TABLE 1

HOUSEKEEPING SCALE FACTORS

HOUSEKEEPING PARAMETER	LINEARITY	WHEN TAPE CHARACTER CHARACTER REPRESENTS 0V	WHEN TAPE CHARACTER CHARACTER REPRESENTS 5.00V	COMMENTS* OR EQUATIONS
1. Flow rate	Linear	Has offset such that extrapolated output is 0.32 V at zero flow (0.48 V actual)	8.6 cm ³ /sec	$Q = \frac{110 E_H - 35.2}{60} \text{ cm}^3/\text{sec}$
2. Altitude (CIC unit)	Linear	0 KM	30.5 KM	$H = 6.10 E_H \text{ kilometers}$
3. Laser power	Linear			$I \text{ photodiode} = 1.00 E_H \mu\text{a}$
4. Electronics Temperature	Non-Linear			
5. PM #1 temp.	Non-Linear	Cold Temperature Asymptote	Hot Temperature Asymptote	$T = \left(\frac{298}{1 + .0806 \ln \left(\frac{5}{E_H} - 1 \right)} - 273 \right) ^\circ\text{C}$
6. PM #2 temp.	Non-Linear			
7. High voltage	Linear	0	2500 V	Expanded scale may be more useful in the future
8. Battery voltage	Linear	0 V	-50 V	Nominal value = -28 V
9. Battery current	Linear	0 Amperes	10 Amperes	Nominal value = 8 amperes
10. Ambient Temp.	Non-Linear			
11. Laser Temp.	Non-Linear	Cold Temperature Asymptote	Hot Temperature Asymptote	$T = \left(\frac{298}{1 + .0806 \ln \left(\frac{5}{E_H} - 1 \right)} - 273 \right) ^\circ\text{C}$

TABLE 1 (Contd.)

12.	Laser current	Linear	0ma	1.00 amperes	Nominal Value: 0.45 amperes
13.	Reference 0y	Linear	-20 mV	---	Nominal Value: +0.020 V
14.	Reference 5v	Linear	---	5.040 V	Nominal Value: 4.96 V
15.	Binary Hours	Linear	0 Hrs		Hours portion of elapsed time from binary 0 to binary 8
16.	Binary Minutes	Linear	0 Minutes		Minutes portion of elapsed time in binary form from binary 0 to binary 59

* Note: E_H represents the housekeeping output voltage and is given by $\frac{5.00}{256} A_B$ where A_B is the binary representation (0 to 255).

where I_p is the associated photomultiplier current and A_B is the binary character stored on the tape. For $A_B = 255$, $I_p = 0.982 \times 10^{-4}(1 \pm 0.018)$ which corresponds to the maximum anticipated level of input current from the photomultiplier anode. The minimum photomultiplier output occurs at $A_B = 0$ which corresponds to $I_p \leq 1.037 \times 10^{-8}$ amperes. At the end of the 3520th character, the special CRC character is inserted after a four character blank interval. Finally, the LRC character is recorded four additional characters later followed by a 0.6 inch blank interval representing the inter-record gap.

b. Sampling

The correction factors required as a result of the method of sampling are now discussed. The method of sampling is such that time is divided into independent increments of 0.01 second. During the first 11/16 portion of each time increment, a sample gate is in the active state and the output of the PM tubes is monitored for the detection of an output signal. The sampling interval is followed by the readout interval which takes place during the remaining 5/16 portion of the 0.01-second time increment. The readout process consists of converting the outputs of the two photomultiplier channels to digital form and translating the digital output to a form suitable for preparing an IBM compatible recording.

c. Method of Correcting for Background Level

If no signal pulses are detected in the 11/16 sampling interval of time increment, a 250-microsecond time strobe is generated beginning 250 microseconds before the end of the sampling interval. This permits a sample to be taken of the background output level of the two PM tubes for every time increment during which no signals are detected. Thus an output will be available for processing at the end of every sampling interval whether an aerosol particle is detected or not. The recording of background levels is useful because it allows the signal contributions resulting from Rayleigh scattering, dark current, dc shifts in the electronics circuitry, etc. to be subtracted out during the data reduction process.

d. Correction for Sampling "Dead" Time

Whenever a particle is detected, the sampling process is turned off for the balance of that 0.01 second time increment. Thus, only the first particle which is detected in each interval will be measured and recorded. In the computer programming, a correction must be

made both for the 5/16 inactive interval in each time increment and for the inactive interval following the detection of each particle. It should be noted that unlike the Geiger counter which has a fixed "dead" time following each detected event, this equipment has a variable "dead" time depending on which portion of the 0.01-second time increment an event occurs. The multiplying factor by which the data rates are corrected is given by

$$\rho = \frac{16 \ln(N_t/N_o)}{11 (1 - N_o/N_t)}$$

where N_o is the number of intervals out of N_t successive intervals during which no pulses are detected.

Because of the background sampling which occurs in every sampling interval during which no pulse is observed, the quantity N_o is not obtained readily. It would have been desirable to indicate the occurrence of a background sample by means of a flag bit associated with each character recorded on tape but unfortunately the entire 8 bits had to be used to meet the system accuracy requirements. Thus, it was not possible to incorporate such a flag bit in the present design. Consequently, it is necessary to determine N_o using a computer program to scan the data. The programming should be such that only data which correspond to light pulses with amplitudes less than the system triggering level will be entered into the N_o count.

The maximum length of time over which the count, N_t , may be taken is related to how rapidly the statistical properties of the particles being measured are changing. If the count rate of the detected particles is not changing the interval, N_t , may be set arbitrarily. For convenience, the number of samples in a record ($N_t = 1744$) might be used for the determination of the ratio N_o/N_t .

The sampled volume associated with each record is given by 1744 samples x 0.01 second per sample x flow rate = 17.44 x flow rate.

The first 0.16 second and the last 2.4 seconds of each 20-second record interval should be disregarded because these intervals are employed for housekeeping and the inter-record blank interval on the tape. During these two intervals any particles which happen to be detected are discarded automatically.

e. Other Computational Considerations

The corrections for variations in volumetric sampling rate can be obtained conveniently by making use of the flow rate parameter

which is recorded during the housekeeping mode of operation when these 15 separate parameters are sampled and recorded. The sampling rate, once every twenty seconds, is comfortably higher than the anticipated rate of change of any of the housekeeping parameters during the experiment.

An absolute value of laser power is required for the smaller particle sizes (below $\alpha = 2$) for which the computation makes use of the direct outputs of the 10 and 30-degree channels rather than the ratio of the outputs. It is anticipated that the laser power parameter can be utilized directly in the computer program without modification. However, because the laser power parameter is monitored by a silicon photodiode a temperature correction may be required. This can be accomplished using the laser temperature parameter which is available as one of the housekeeping parameters and can therefore be incorporated, if needed, into the computer program. The temperature parameter is non-linear; therefore, the calibration curve which is provided with each temperature sensor is used in the determination of temperature.

In most cases the accuracy to which temperature must be known in order to perform corrections for temperature dependent parameters is not very critical. Therefore, in place of a calibration curve an equation with three calibration constants (C_1 , C_2 and C_3) can be used. In terms of the binary character, A_B , stored on the tape the equation is given by

$$T = \frac{C_1}{1 + C_2 \ln \left(\frac{256 - A_B}{256 - A_{Bo}} \cdot \frac{A_{Bo}}{A_B} \right)} - C_3$$

The binary character A_{Bo} represents the binary character recorded at a temperature of 25°C. Normally $A_{Bo}/(256 - A_{Bo}) \approx 1$.

Using typical values of the calibration constants the equation becomes

$$T = \left(\frac{298}{1 + 0.0806 \ln \frac{(256 - A_B)}{(256 - A_{Bo})} \cdot \frac{A_{Bo}}{A_B}} - 273 \right)^\circ C \approx \frac{298}{1 + 0.0806 \ln \frac{256 - A_B}{A_B}} - 273^\circ C$$

Except for the altitude parameter, the remaining housekeeping parameters are for diagnostic purposes and do not enter into the computations. However, for the first few balloon flights, the computer should be programmed to read out the values of these parameters (at least on a once-per-ten-minute basis).

f. IBM Compatibility

The recording format is such that compatibility to the IBM 360 standards is maintained except for work length. In this system, the eight data bits of each character recorded on tape represent an independent eight bit binary number. The ninth bit represents the vertical parity bit and will be a "one" whenever the other eight bits contain an even number of ones.

3. Rationale for Processing Scientific Data

The primary scientific data input consists of pairs of maximum intensities measured in the 10 and 30-degree channels for a specific sampling time. These data are compared with those derived from Mie scattering calculations as modified by experimentally determined calibration data. Using these calibration data, two comparison curves are constructed, the first corresponding to analysis based on the ratio of the scattering intensities into the 10 and 30-degree channel, which is appropriate for particles with α exceeding 2.0 as shown in Figure 2. The second curve presented in Figure 3 corresponds to analysis based on the absolute intensity of the scattered signal into the 10-degree channel, which is appropriate for particles with α less than 2.0.

Care must be exercised to obtain continuity at the α -value of 2.0. This is a natural consequence of the fact that two different data reduction schemes are employed at higher and lower α -values respectively, so that some residual discontinuities arising from small errors in the separate calibration constants and/or extrapolation of the fitted curves, are to be anticipated.

The first step in the analysis of a data pair consists of making a decision as to whether it is likely that a particle was detected during the sampling period. Let I_{10} and I_{30} represent the recorded signals and let T_{10} and T_{30} represent threshold criteria specified as input data. One has four possible conditions:

- (1) $I_{10} \leq T_{10}$ and $I_{30} \leq T_{30}$. This condition indicates that no particle has been detected. The values I_{10} and I_{30} are used, along with other pairs in the record which satisfy the same condition to calculate a mean background figure for the record.
- (2) $I_{10} \leq T_{10}$ and $I_{30} > T_{30}$. This condition probably indicates noise in the 30-degree channel. The data are ignored.
- (3) $I_{10} > T_{10}$ and $I_{30} \leq T_{30}$. This condition probably indicates noise in the 10-degree channel. The data are ignored.

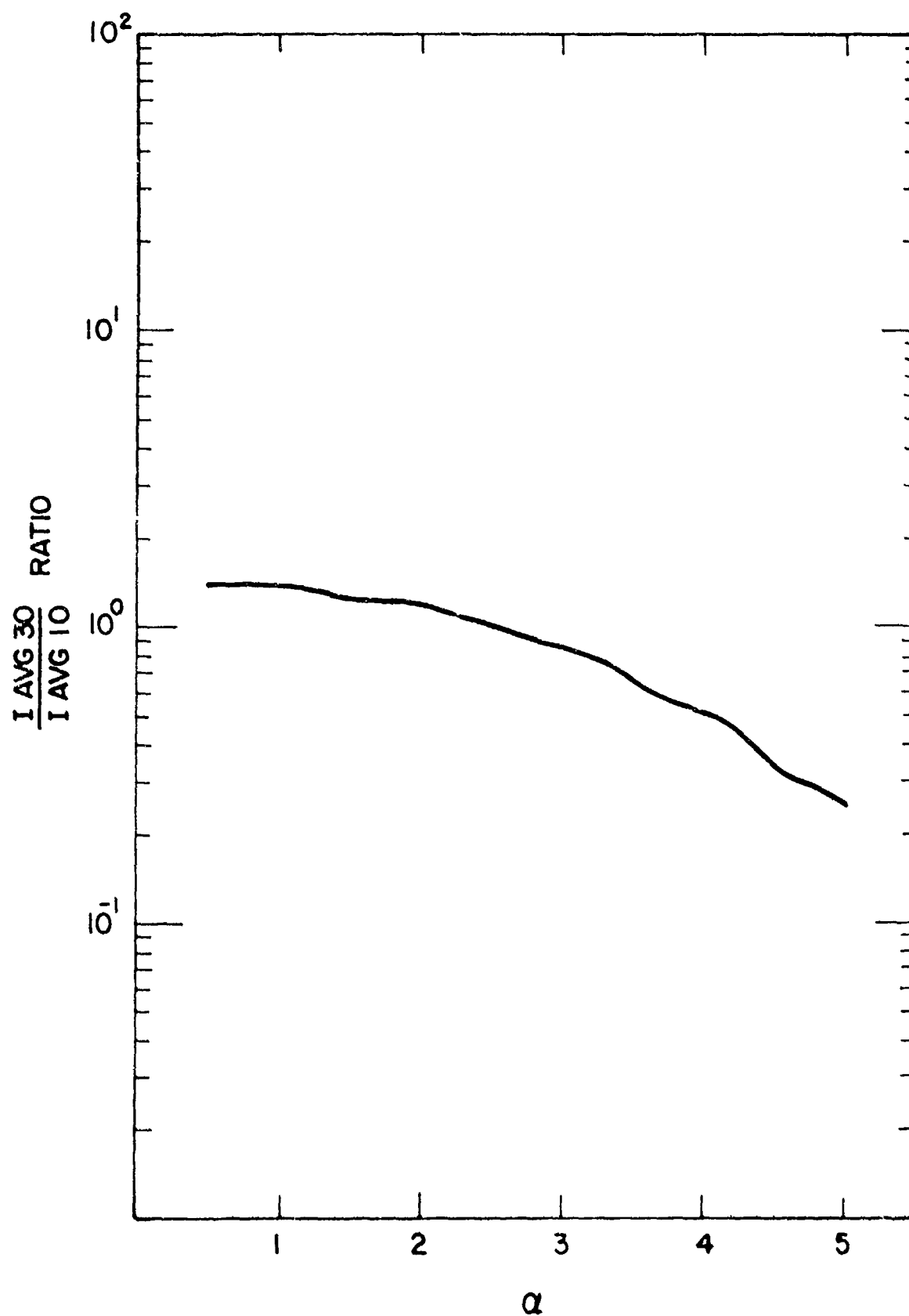


Figure 2. Comparison curve used with the ratio technique.

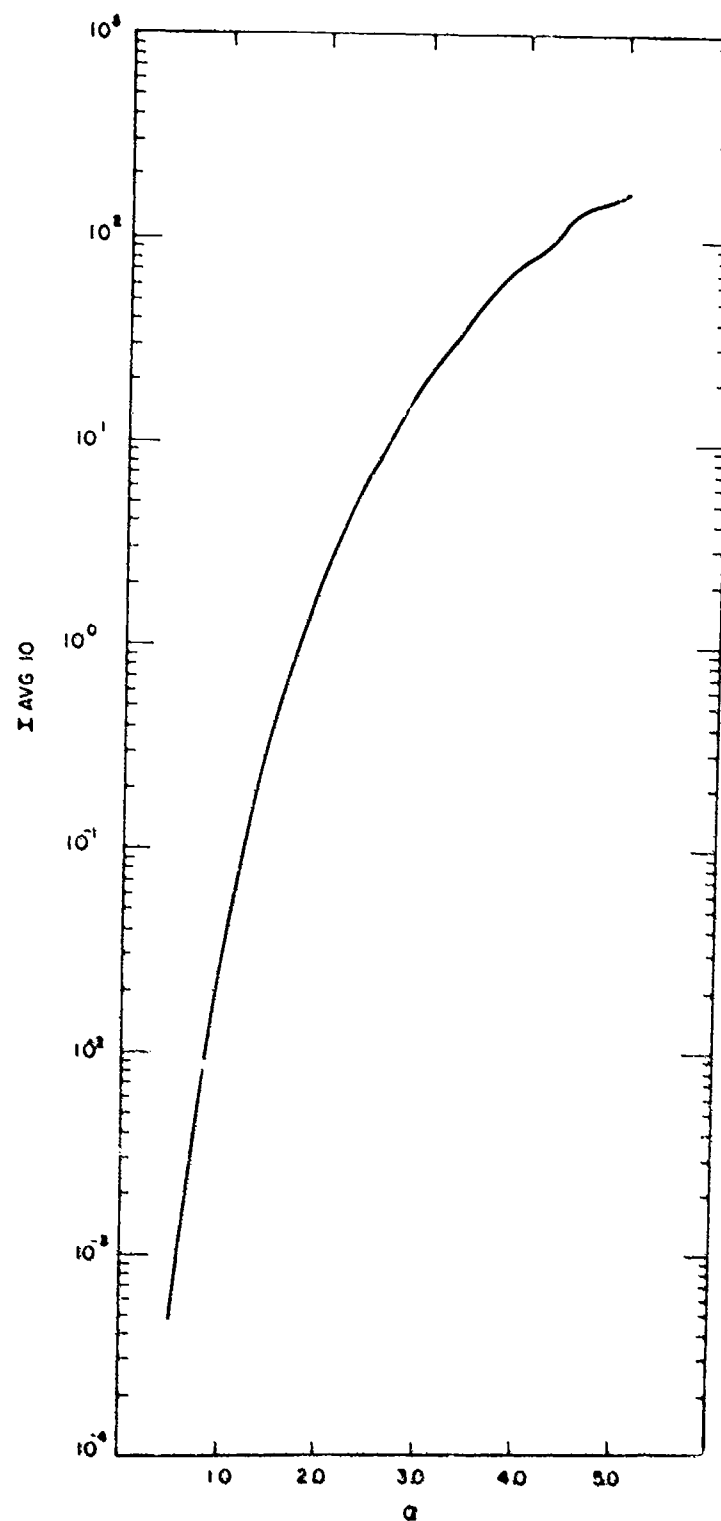


Figure 3. Comparison curve used with the absolute value technique.

- (4) $I_{10} > T_{10}$ and $I_{30} > T_{30}$. This condition indicates detection of a particle, and the information is stored for subsequent treatment along with other such pairs in the record.

It has been found from experience that the occurrence of conditions (2) and (3) is relatively infrequent as compared with the occurrence of condition (1), so that the accuracy of establishing a background level is affected little by the fact that these data are ignored. However, it should be pointed out that this is a consequence of selecting the threshold criterion well above the "noise" level. Should it be found desirable in the future to reduce the threshold criterion (e.g., in pursuit of smaller pulses), then this question should be re-examined.

After all 1744 data pairs of the record of interest are examined using criteria (1) through (4), the mean background values for the 10 and 30-degree channels are calculated using those data which satisfies condition (1) above. These mean values are then subtracted from those raw data pair values which satisfy criterion (4). In this manner an approximate correction for background level is applied to the pulse height data.

The data pairs, corrected in the above manner, are next sorted with respect to the comparison curves (Figures 2 and 3) in order to determine the particle size. First, the ratio of the corrected data pair is calculated, and compared with the tabulated values which were employed to generate Figure 2. If the calculated ratio is greater than the value corresponding to $\alpha = 2$ in Figure 2, it is assumed that the particle is small, and processing by the absolute intensity method is initiated. However, if the ratio is smaller than that appropriate for $\alpha = 2$, one initially assumes that the particle has $\alpha > 2$ and the ratio method is appropriate. However, before it is finally assumed that the particle is large ($\alpha > 2$), and treated appropriately, a check is made to insure that the amplitude in the 10-degree channel is high enough to correspond to a large particle. In order to satisfy the test, the amplitude in the 10-degree channel must exceed the threshold criterion by an order of magnitude which has been selected somewhat arbitrarily. It is significantly less than the expected amplitude in the 10-degree channel for particles with $\alpha = 2.0$.

If the amplitude in the 10-degree channel does not satisfy this condition (the absolute amplitudes increase very rapidly for particles of $\alpha < 2$), the pulse is treated using the absolute amplitude method, thus implicitly assuming some noise in the 30-degree channel. However, if the data satisfy both the ratio and absolute criteria for larger particles, the size is determined by inverse tabular interpolation using Figure 2, and the value is stored to average with other values from the given record and other records being averaged for the desired altitude increment.

Assuming the the corrected data for a given pair has a ratio greater than that appropriate for $\alpha = 2$ particles, or if the ratio is larger, but the amplitude in the 10-degree channel does not exceed $10 T_{10}$, the size of the particle is determined using inverse tabular interpolation in Figure 3. However, data treated in this way are ignored if the value of α determined from inverse interpolation from Figure 3 exceeds 2.5. No such cases have been encountered so far in the data analysis performed to date.

A schematic flow chart may help in a detailed understanding of the above sequence of operations given in Figures 4 and 5. For each record processes, a count of the method for individual pairs is maintained in the following manner:

- (a) Number of detected particles which satisfy the ratio criterion and the magnitude criterion for the 10-degree channel appropriate for large ($\alpha > 2$) particles
- (b) number of detected particles which satisfy the ratio criterion for small particles, and, for which the assigned α is less than 2.0
- (c) number of detected particles which satisfy the ratio criterion for large particles but for which the amplitude in the 10-degree channel indicates that the particle is small
- (d) number of detected particles, which, using the absolute intensity analysis method, despite ratios corresponding to large α -values, gives values of α exceeding 2.0 but less than 2.5. For these detected particles, the bin number in the α range is given so one can see what α value is assigned
- (e) number of detected particles, which, using the absolute intensity method, gives values for α exceeding 2.5.

An investigation of the data records processed to date indicates:

- (1) A small number of detected particles have been treated by method (a) above.
- (2) A much larger number of detected particles have been treated according to prescription (b) above.
- (3) A rather large number of detected particles have been treated by prescription (c) above. This may indicate calibration or threshold errors.
- (4) A very small number of detected particles have been treated by method (d) above.
- (5) None of the particles have been treated using logical route (e) above, to date.

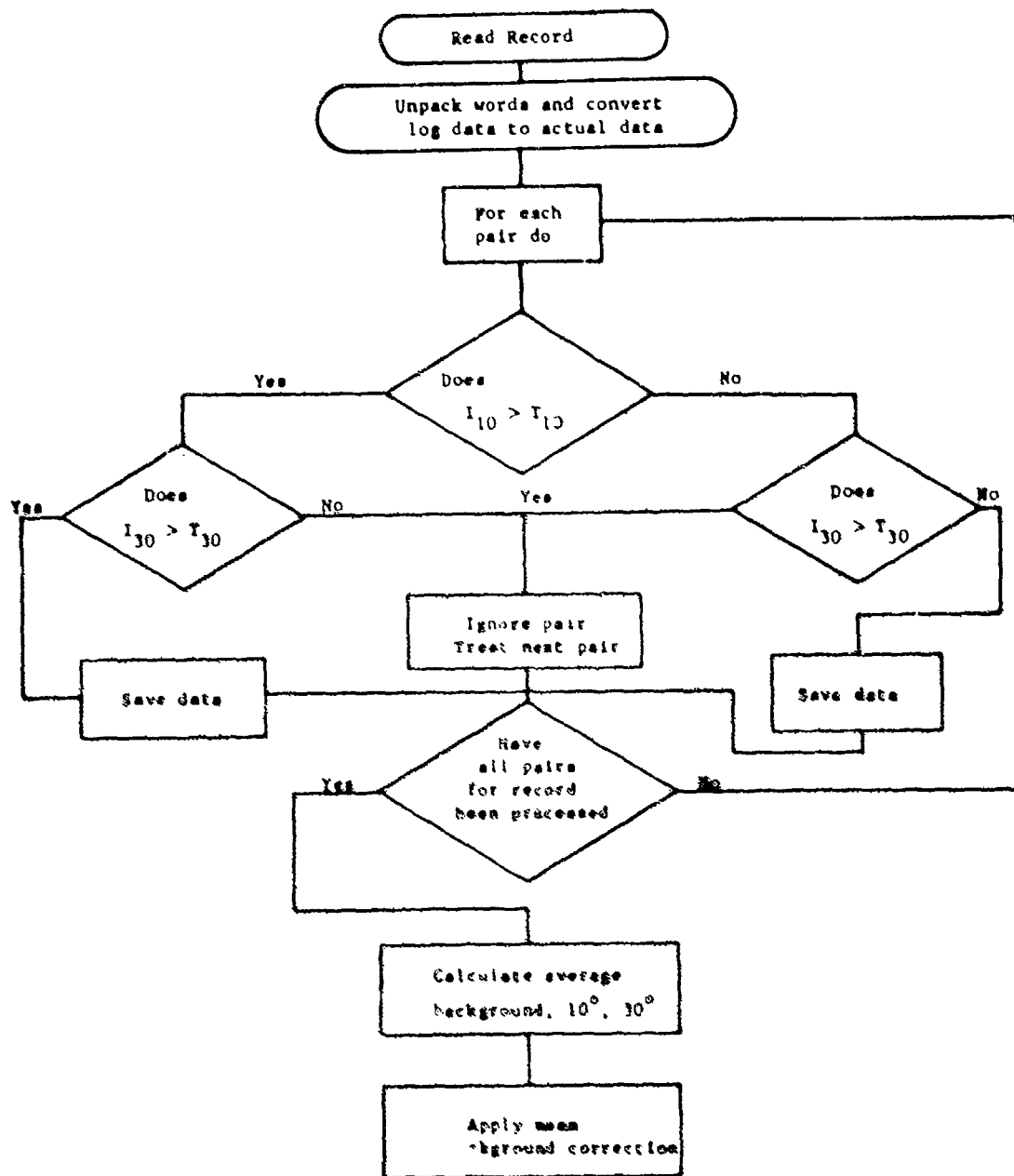


Figure 4. Schematic flow chart of computer processing for pulse pair sorting.

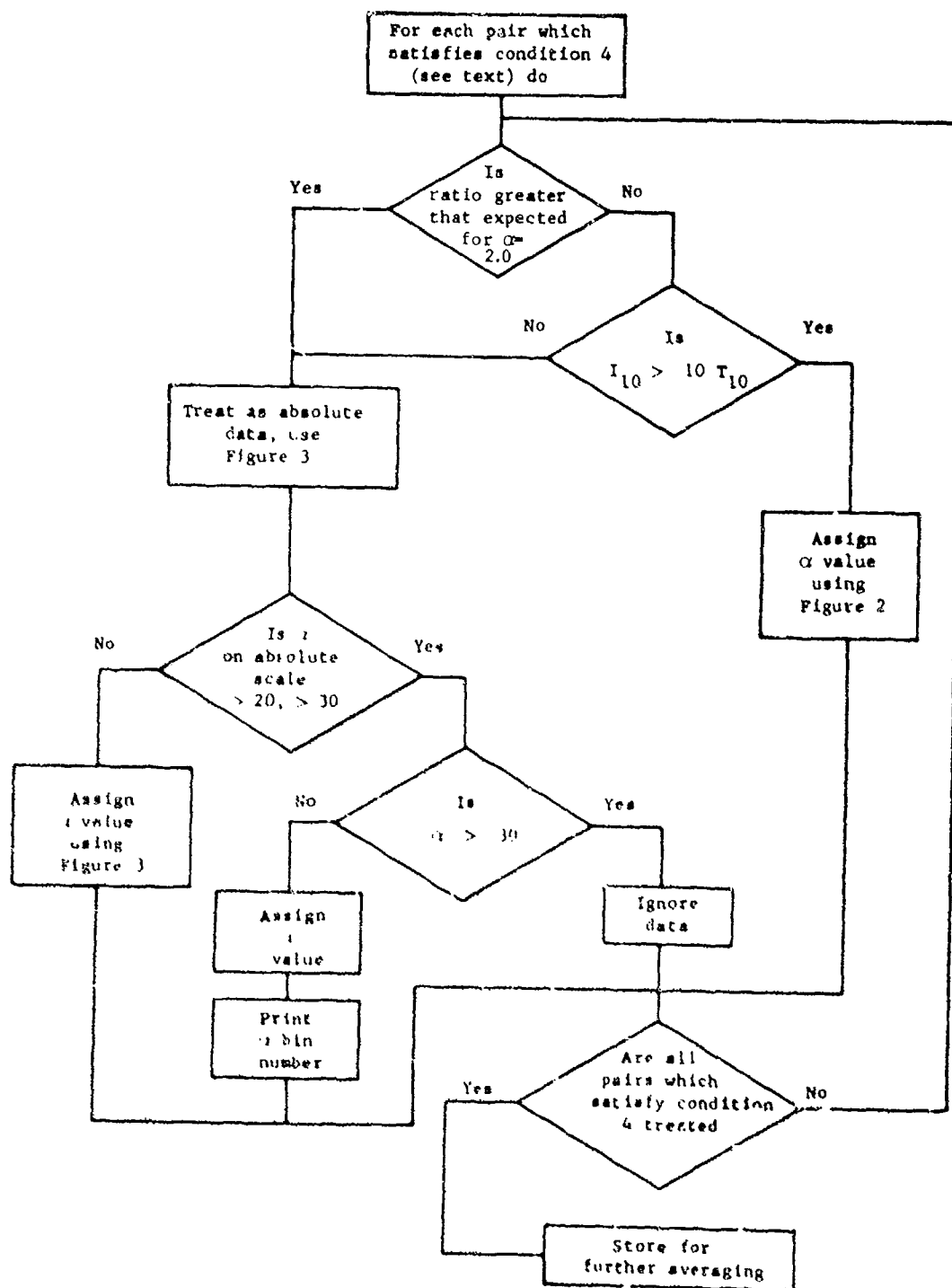


Figure 5. Schematic flow chart of computer processing for particle sizing.

From the preceeding, it is evident that the data have been reduced in only a preliminary fashion to date and that additional numerical experiments must be performed using the existing flight data in order to optimize the procedure. The following discussion delineates several specific recommended measures in this regard.

- (i) An attempt should be made to establish a pulse criterion which is better suited for the identification of smaller pulses than that presently in use. Numerical experiments to this end should be addressed first to assessing the sensitivity of the derived results upon this parameter.
- (ii) The data reduction method should be modified in order to better allow for possible discontinuities of the data for particles near $\alpha = 2.0$, where reduction procedures change from absolute to ratio.
- (iii) Use of the 30-degree channel in place of the 10-degree channel for the absolute size determination mode, should be explored. Selection of the 10-degree channel in the present scheme was made on the basis that this channel provided greater accuracy in the determination of α , by virtue of a steeper slope for the output-versus- α curve. However, this advantage was gained at the expense of greatly reduced sensitivity for smaller particles. A trade-off in the reverse direction might well be desirable.
- (iv) The present program leads to incorrect record counts if the final record of an altitude sub-average for total particle concentration shows low flow rate (and is thus ignored). This should be corrected.
- (v) Modification of the program should be made so that the total number of particles assigned to each α -increment, during the processing of those records resulting in a particle size distribution, are outputted. This additional output datum would enable estimation of the expected errors due to the counting statistics.

A listing of the current program, together with a description of the input data, is given in Appendix A.

C. BALLOON FLIGHT RESULTS

The preliminary results of the 28 October balloon flight are presented here with no attempt to analyze or interpret same. Size distributions for 8 to 10, 10 to 12, 12 to 14, 14 to 16, 16 to 18, and 18 to 20 kilometers on the upleg portion are presented in Figures 6 through 11 respectively. Figure 12 pertains to float altitude (i.e., > 23 km), while Figures 13 through 18 show the respective downleg size distributions for the following height intervals: 22 to 21, 21.5 to 20.5, 20.5 to 19.5, 19.5 to 18.5, 18.5 to 17.5, and 17.5 to 16.5 kilometers. Upleg data for other portions of the flight have not been included here owing to negative flow rates, as discussed previously. In addition, owing to the fact that the flight lasted longer than the six-hour recording interval, downleg data below 16.5 km were not recorded. Note that all figures indicate the presence of a peak at $\alpha = 1.1 - 1.2$. This is believed to be a consequence of the present manner in which threshold criteria are applied in the computer program, as discussed in the previous section of this report. It should also be noted that a tendency is shown for greater spread in the data for that portion of the size distribution greater than about $\alpha = 2.5$. Although it is tempting to ascribe this to statistics on the ground that smaller total counts have been recorded in this size regime, the transition is too abrupt to be entirely plausible.

Figure 19 is a plot of total particle (i.e., between 0.2 and 1 micron diam) concentration profile observed during this flight. This shows the well-known peak at about 20 km altitude, as well as the trough between 12 and 18 kilometers, together with the rapid fall-off with increasing altitude below.

The lack of overlap between upleg and downleg data is an unfortunate consequence of the low flow rate conditions, which necessitated the rejection of certain entire portions of the total concentration computation. The effect on size distributions determination on the other hand, is not as severe. These data (namely, 16 to 18 and 18 to 20 kilometer data) have been retained, although the reader is cautioned as to the possible unreliability of the ordinates in these two instances.

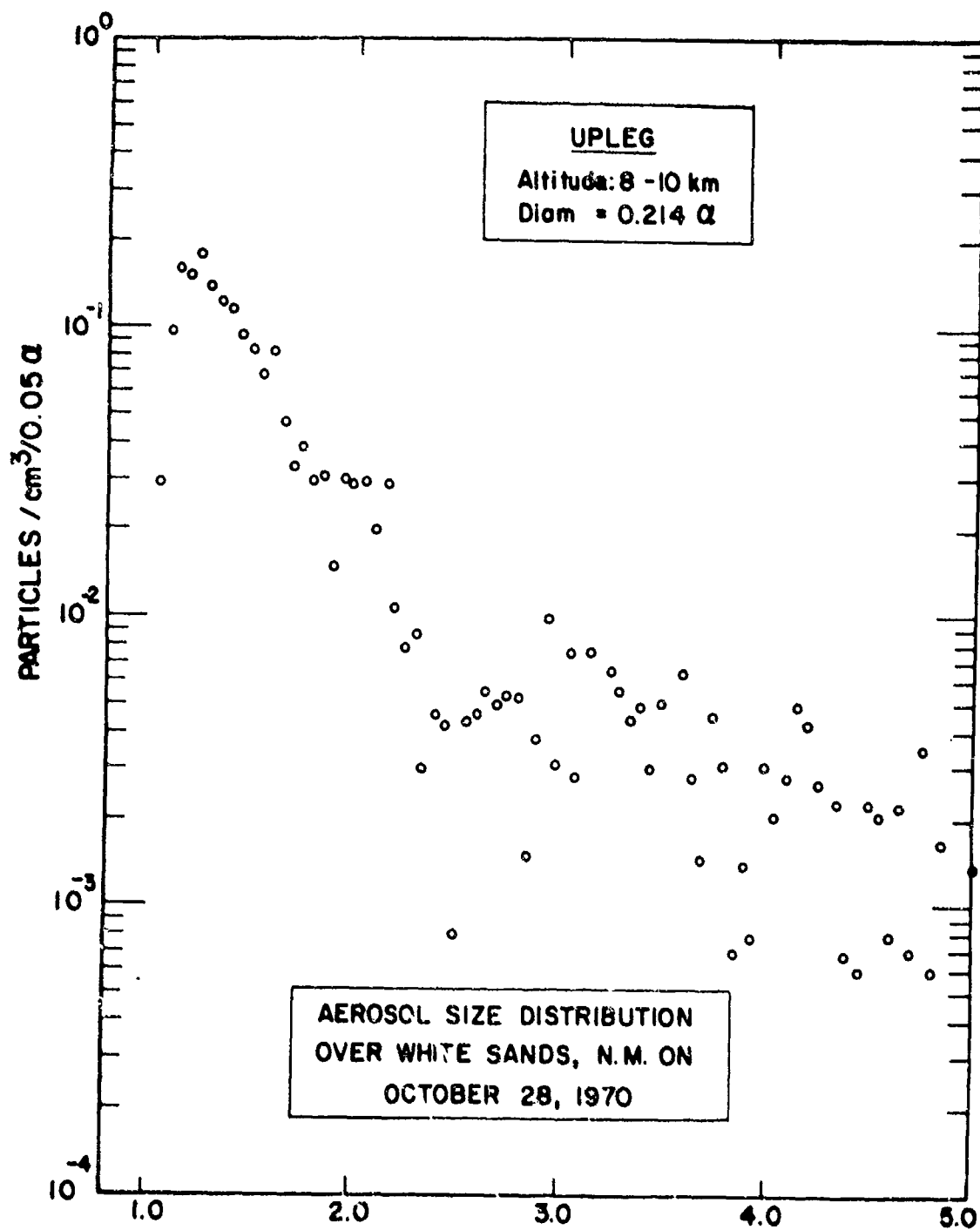


Figure 6

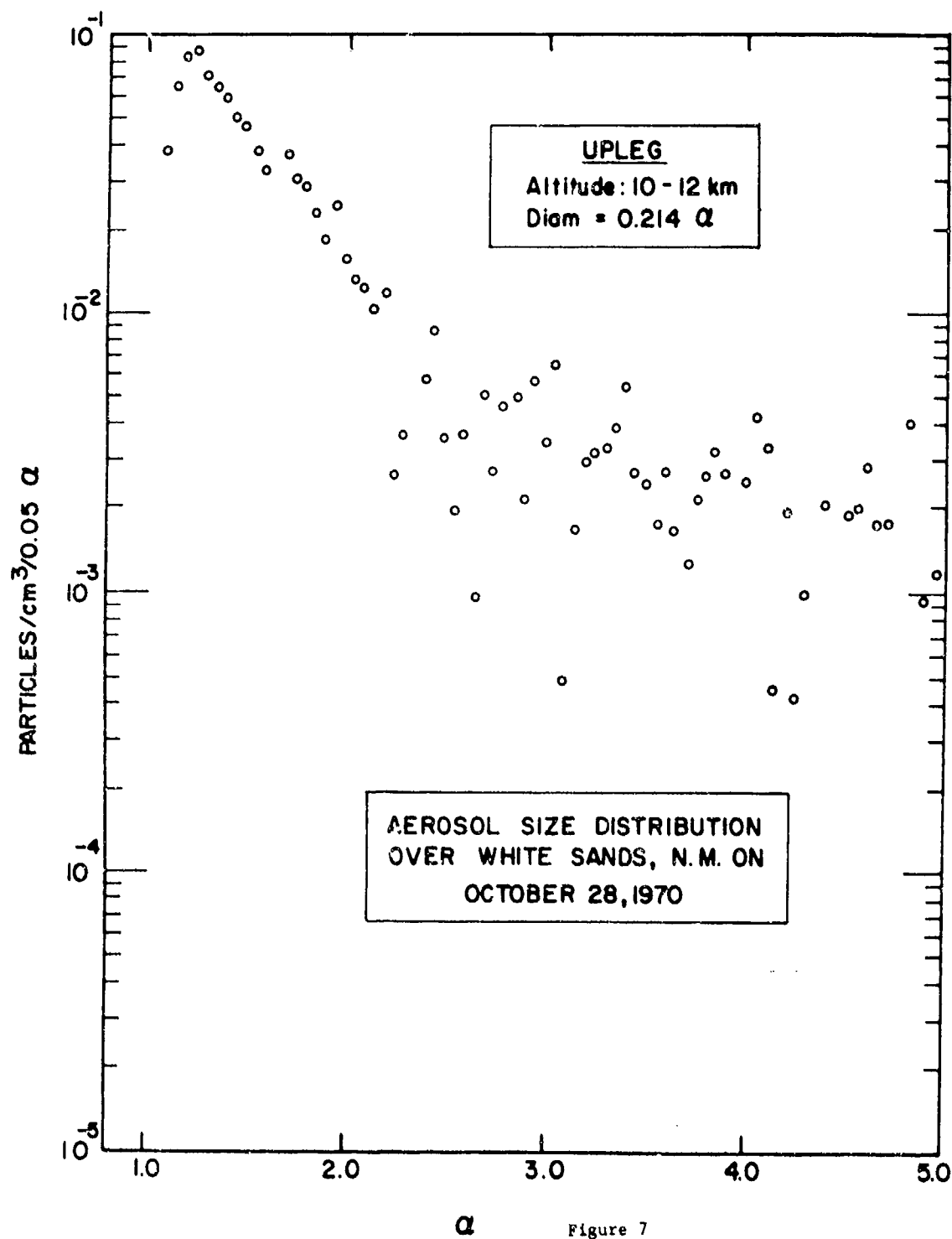


Figure 7

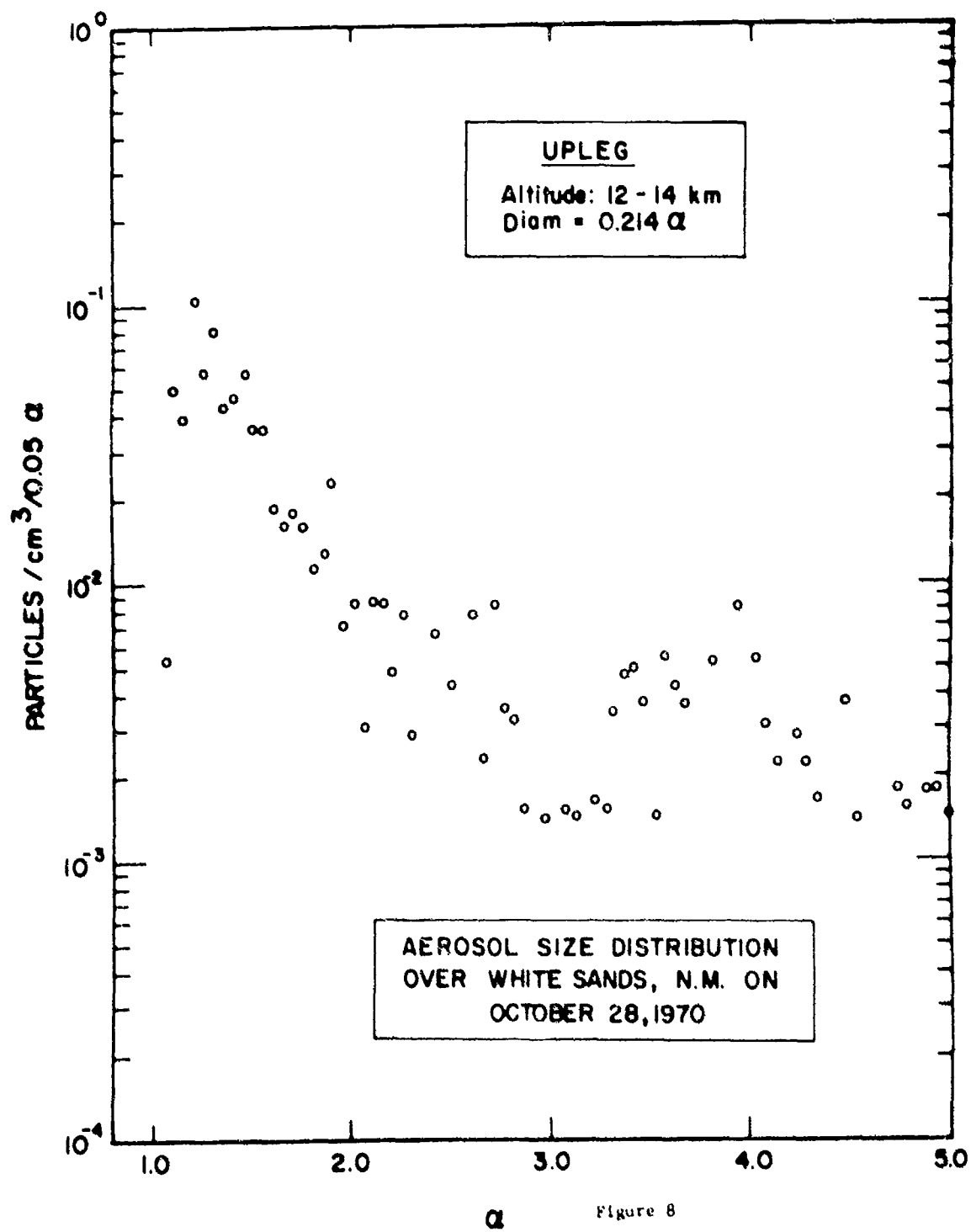
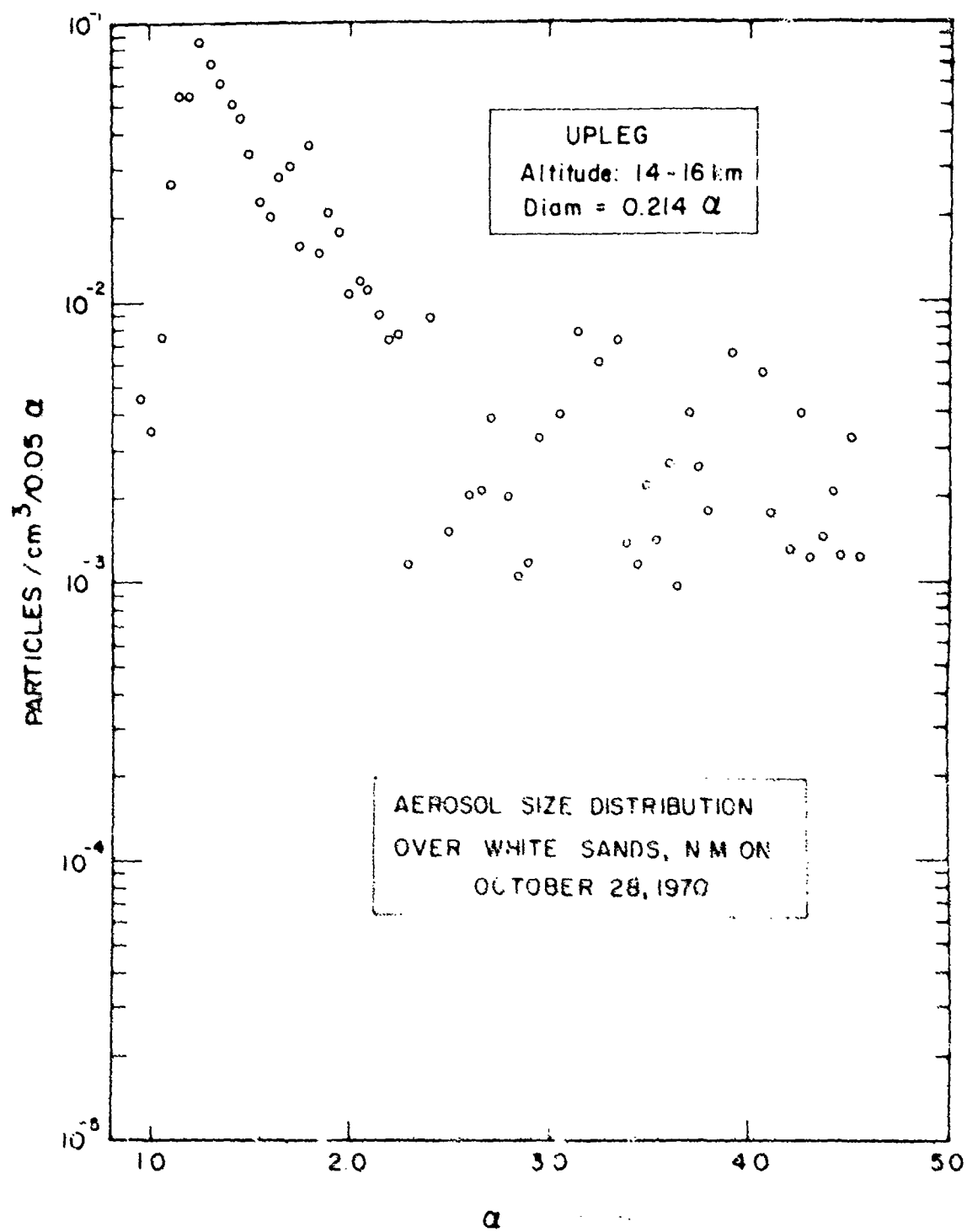


Figure 8



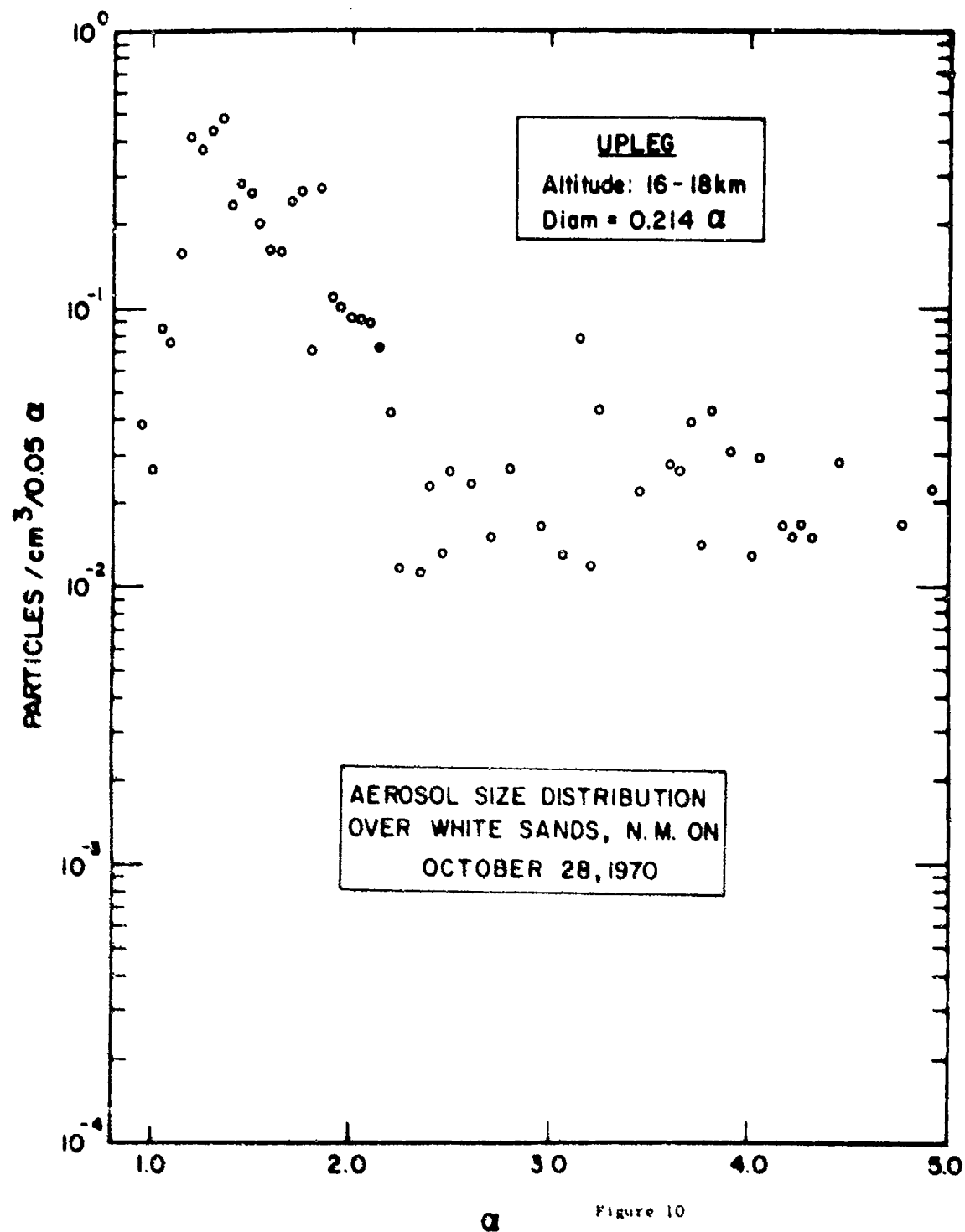


Figure 10

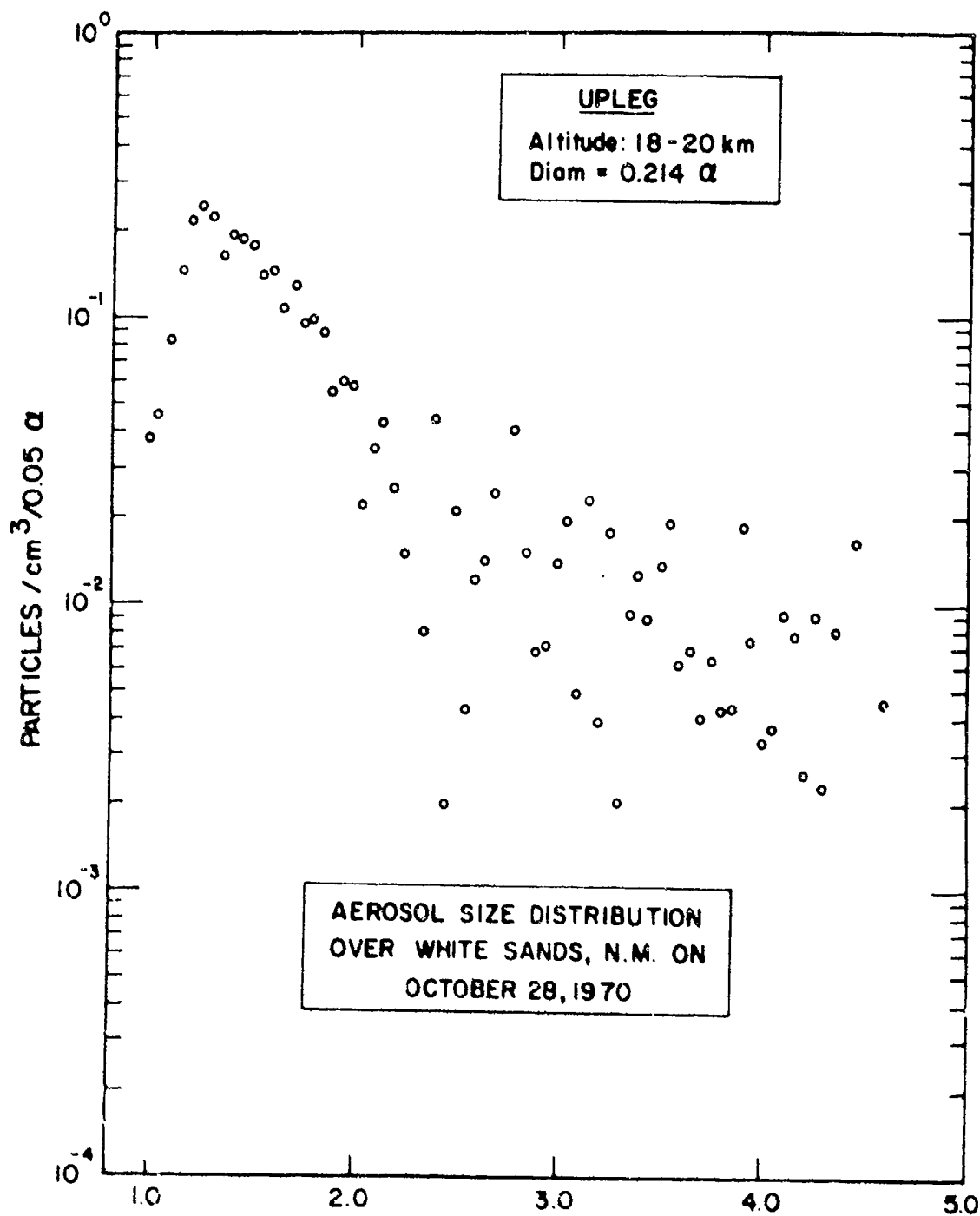


Figure 11

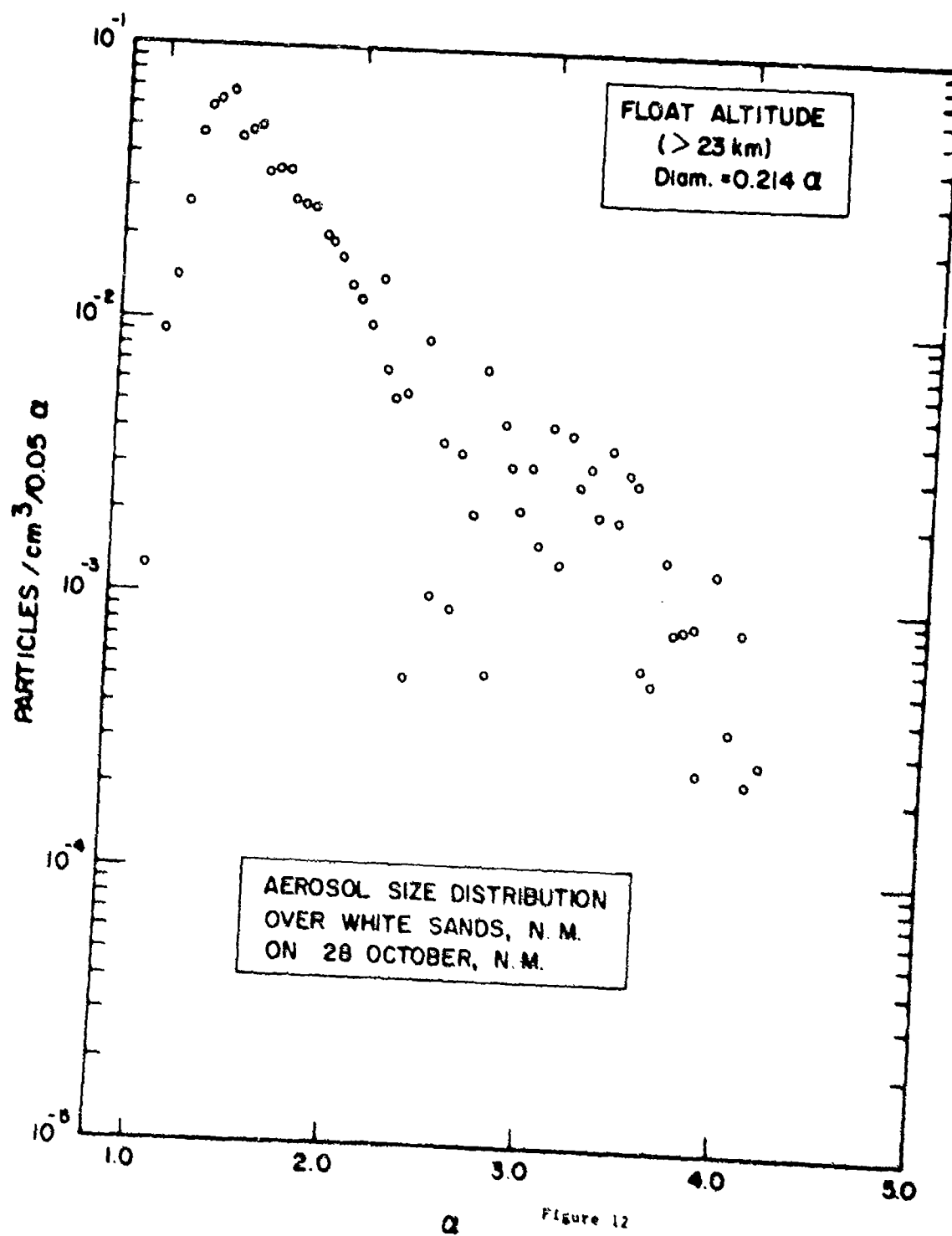


Figure 12

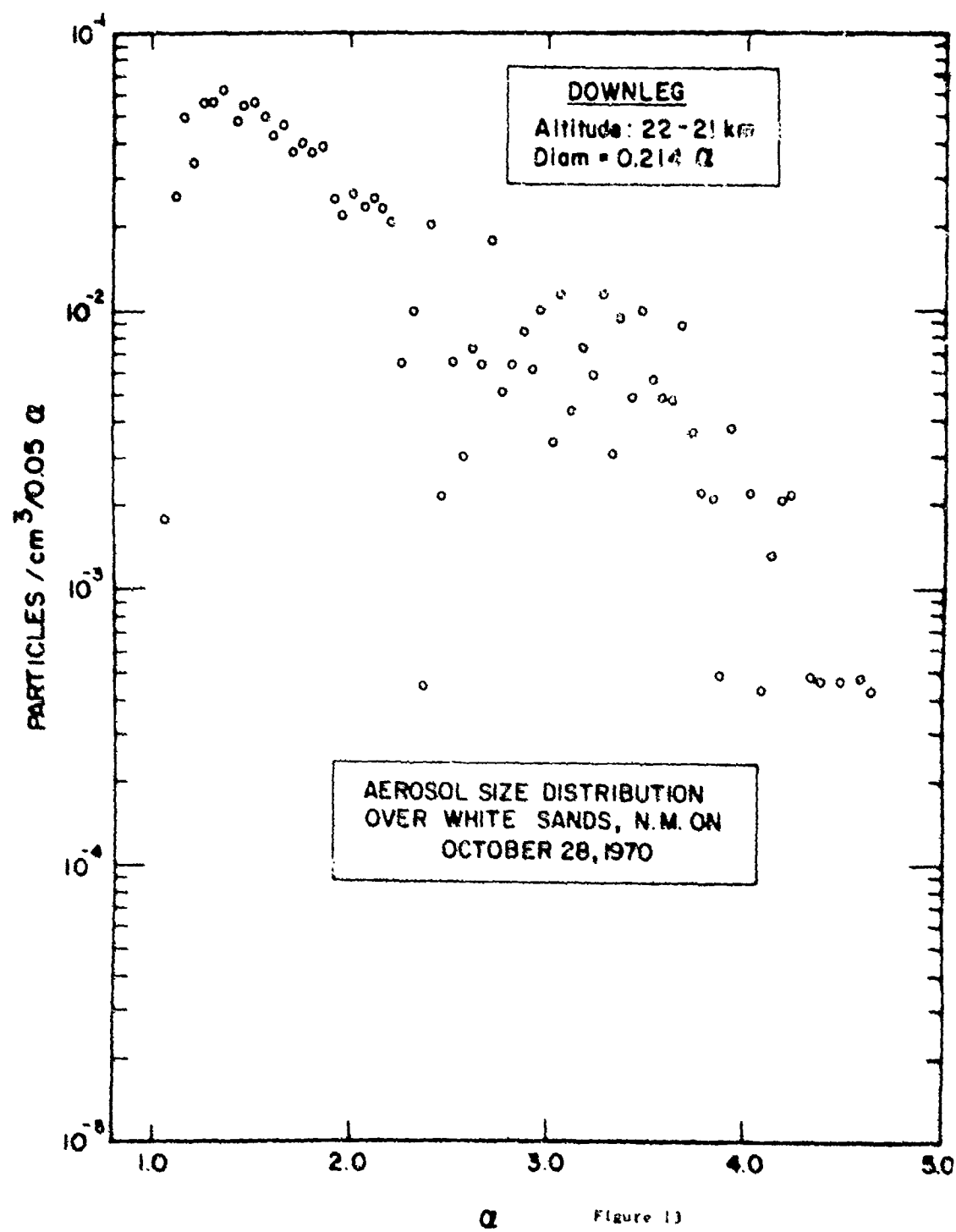


Figure 13

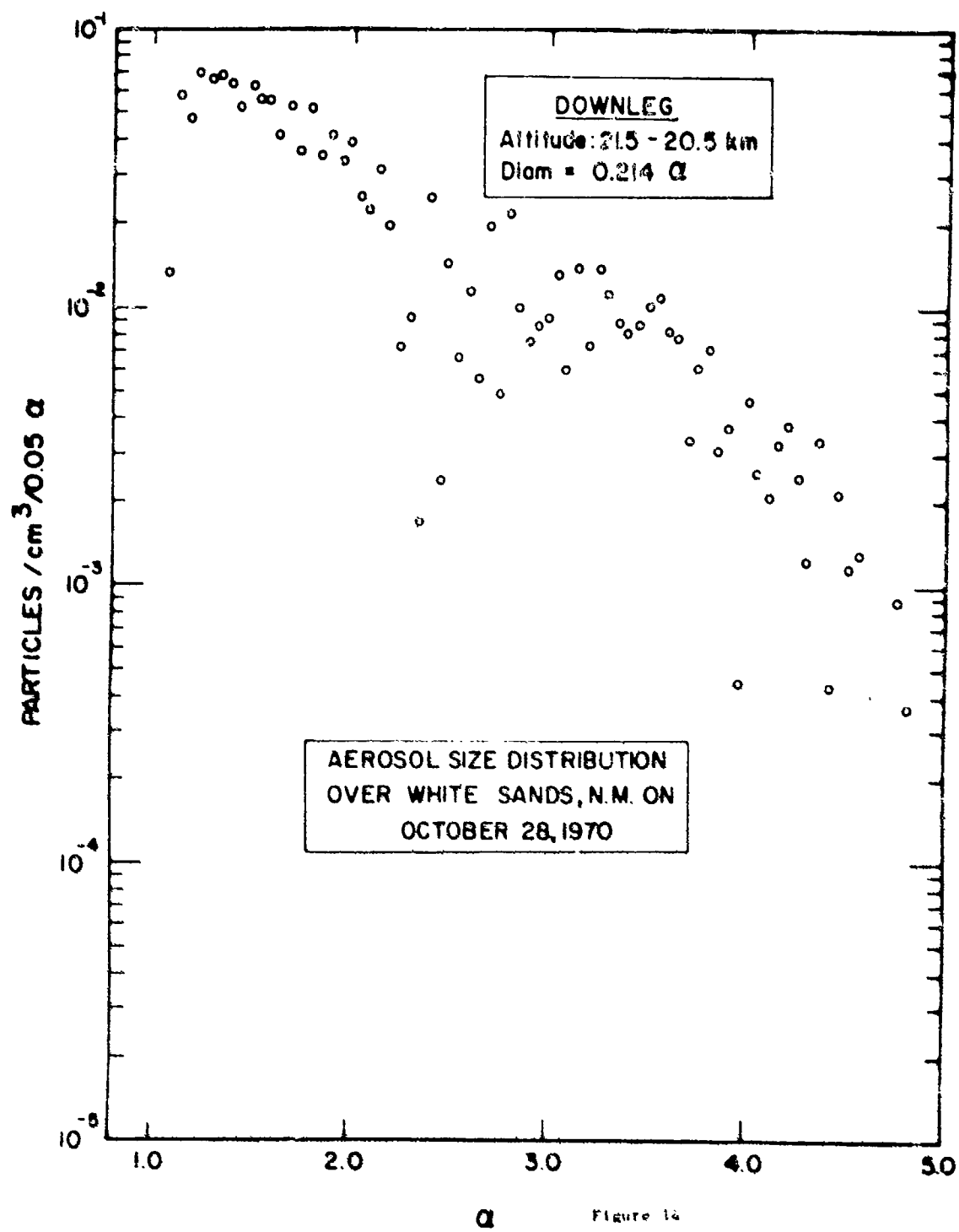


Figure 14

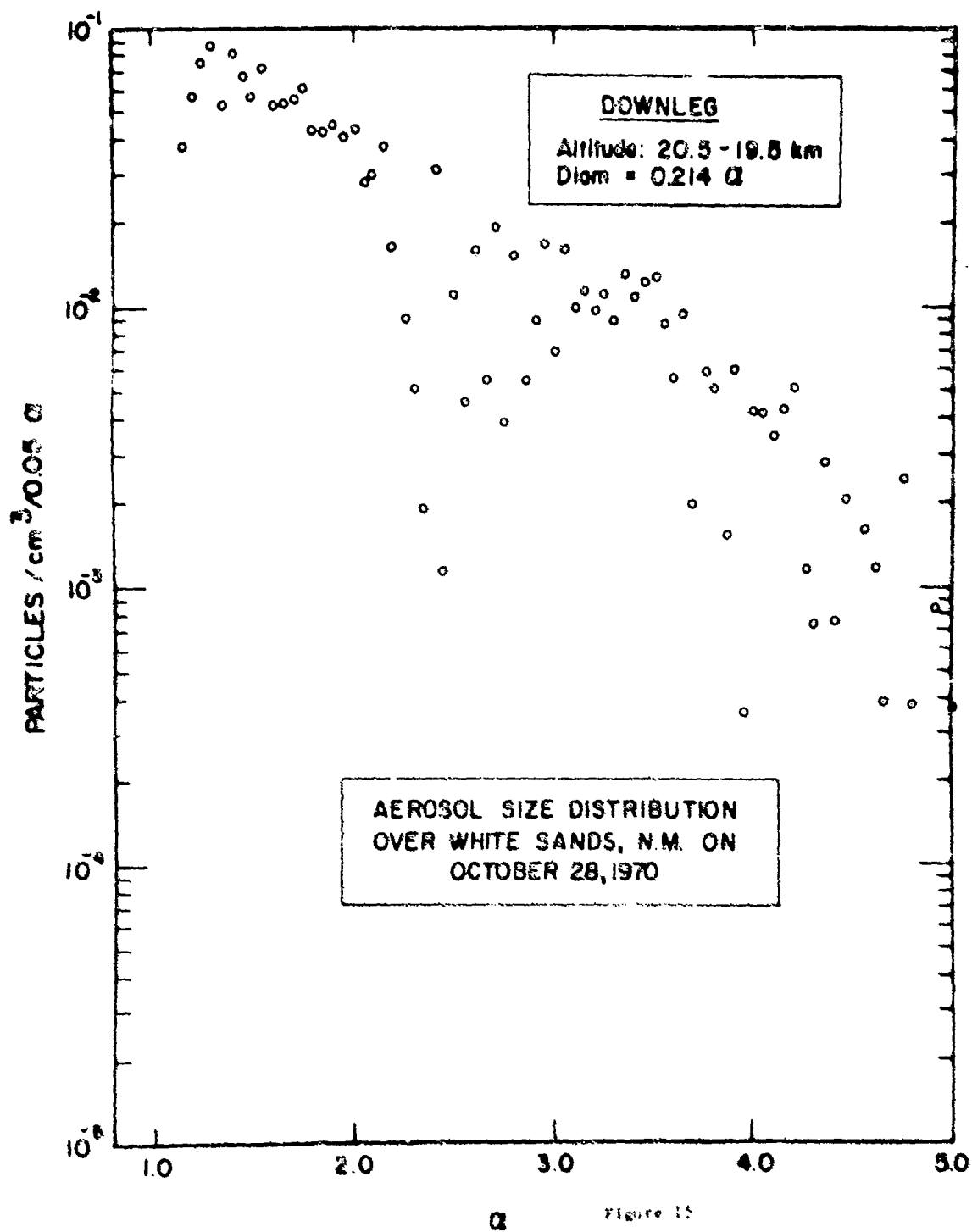


Figure 15

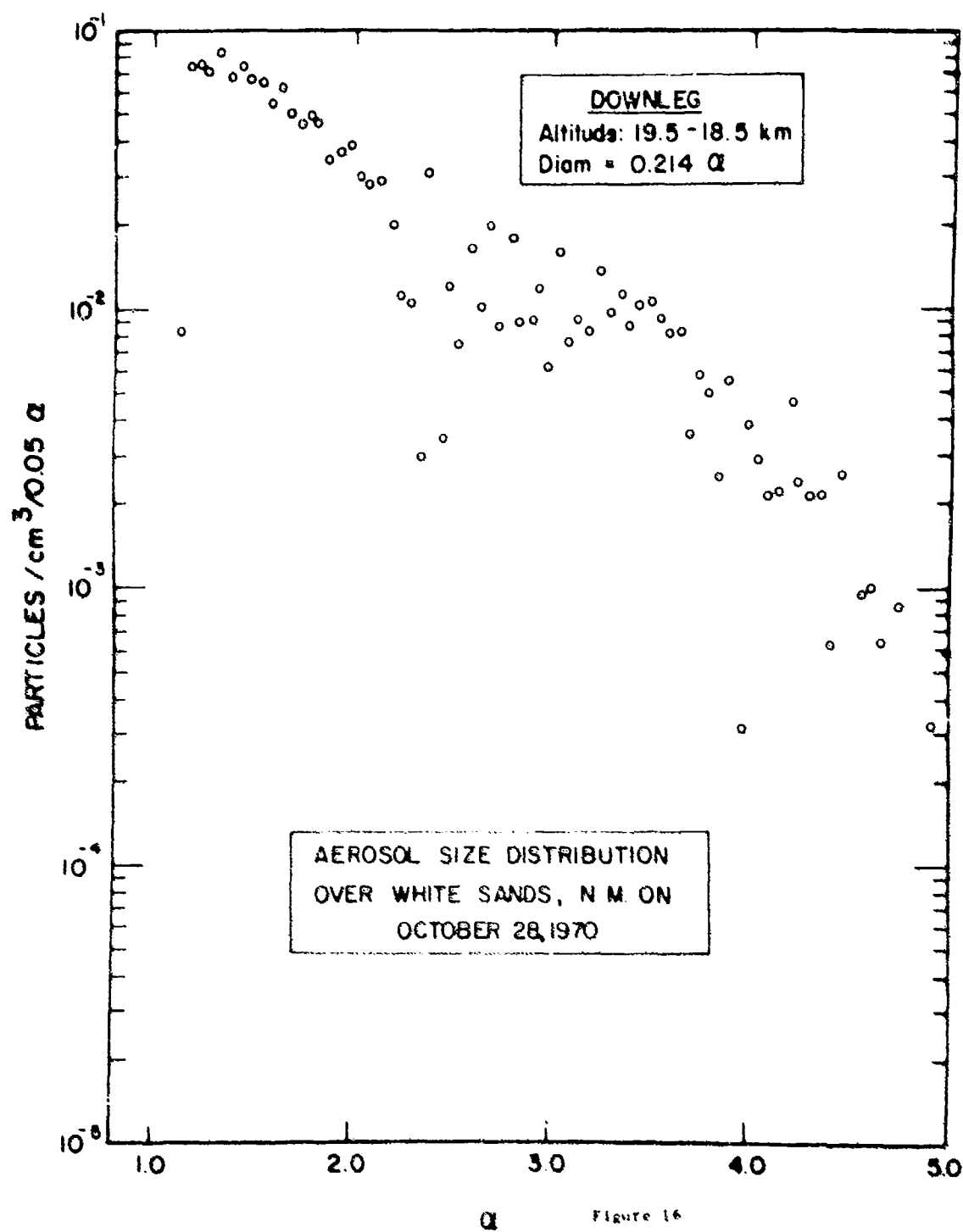


Figure 16

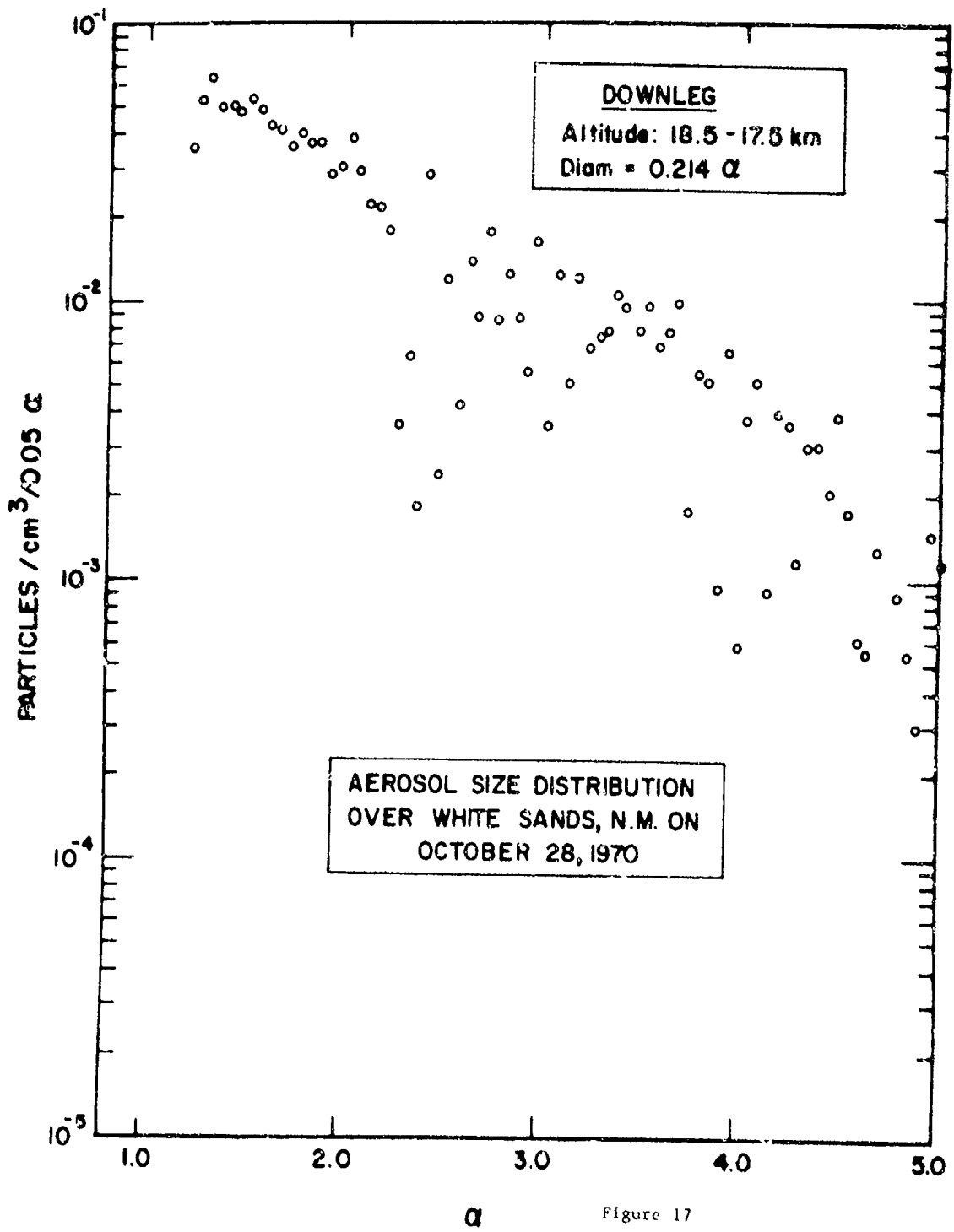
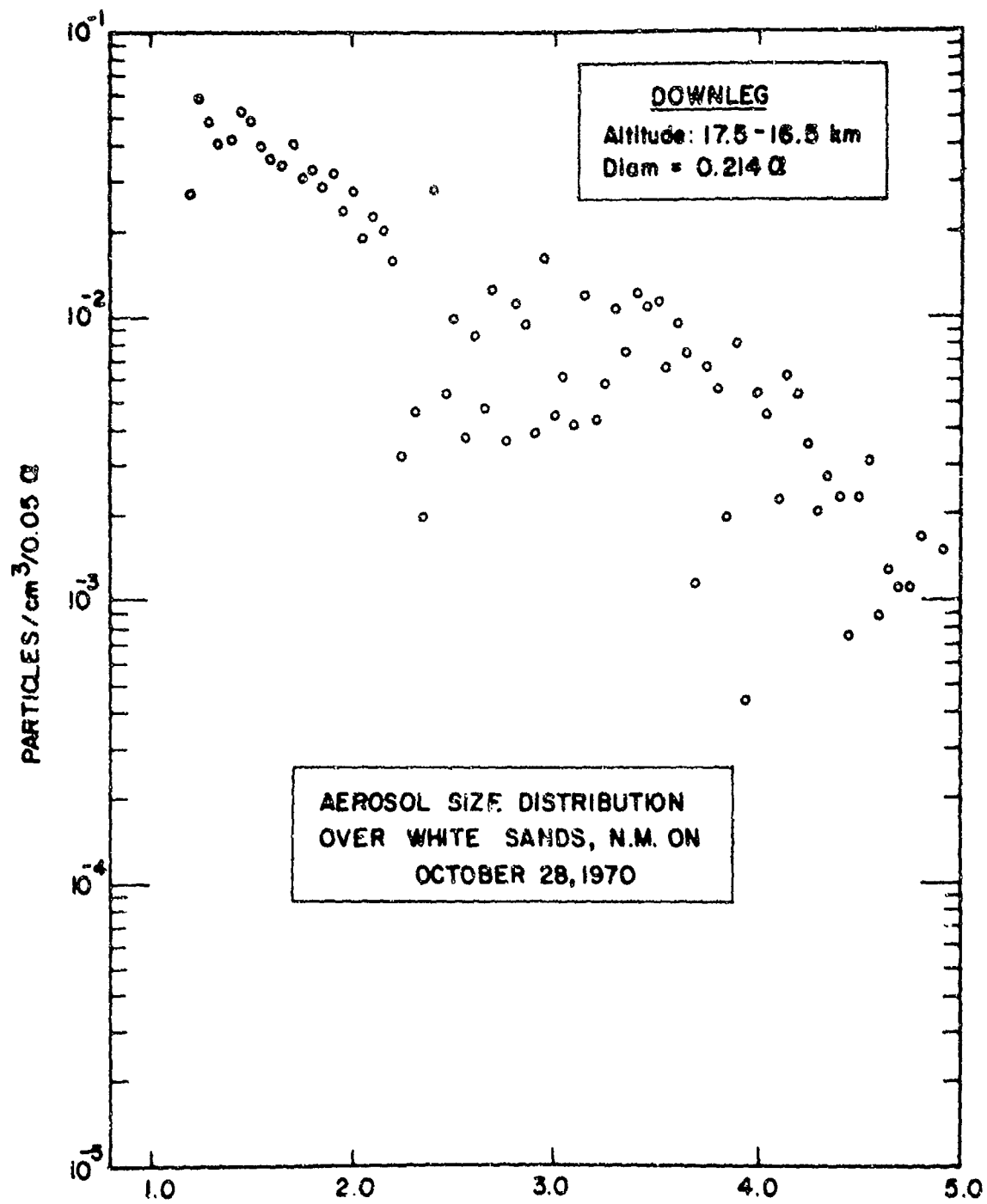


Figure 17

α



α

Figure 18

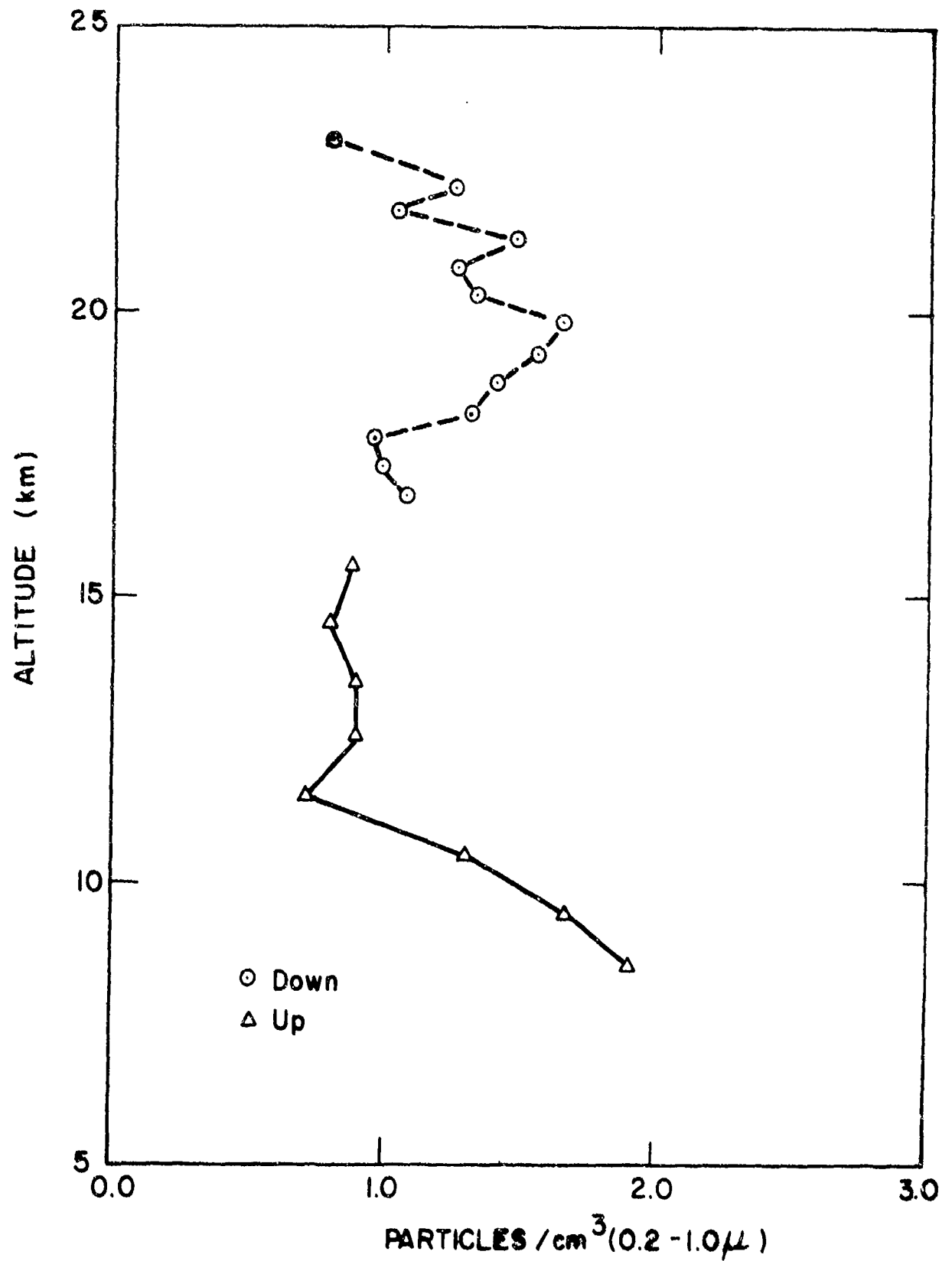


Figure 19. Altitude profile of particle concentration within diameter size range 0.2 - 1.0 micron.

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5. B. Y. H. Liu, et al., "Comparative Size Measurements of Monodisperse Liquid Aerosols by Electrical and Optical Methods", Envir. Sc. Techn. Vol. 3, p. 381, 1969.
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APPENDIX A
PROGRAM LISTING

```

REAL IHOUSE, IDATA, ITRESH, JTRESH
INTEGER*2 JDATA
DIMENSION IHOUSE(32), IDATA(3488), AVG10(91), AVG30(91)
DIMENSION RATIO(91), STORE(91), DATA(3488), BIN(91)
DIMENSION JDATA(1760)
DIMENSION KDATA(1760)
DIMENSION DAR(3488)
DIMENSION NSUB(9)
COMMON      Z, FLOWRT, ALT, ALASER, PHOTO1, PHOTO2, HV, BATVOL, BATAMP,
1ELECTE, ALASTE, ALASC, VOLTL, VOLTH
C
      STORE2=0.0
      DO 11 I=1,91
        STORE(I)=0.0
11 CONTINUE
      IRECNO=0
      REWIND 15
C      READ AVG10 AND AVG30
      READ(5,100) RCONST, ACONST
100 FORMAT (2F10.0)
      READ(5,10) AVG10
10 FORMAT (5E14.5)
      READ(5,10) AVG30
      DO 71 I=1,91
        RATIO(I)=(AVG30(I)/AVG10(I))*RCONST
        AVG10(I)=AVG10(I)*ACONST
71 CONTINUE
      WRITE(6,10) AVG10
      WRITE(6,10) AVG30
      WRITE(6,910) RATIO
910 FORMAT (10E11.3)
C      READ THE NUMBER OF DATA BLOCKS TO BE PROCESSED AND THE TRESHOLDS
      READ(5,4621) IREC, ITRESR, JTRESR
4621 FORMAT(5I5)
      60 FORMAT (15,2F5.0)
C      READ THE HOUSEKEEPING PORTION OF THE DATA BLOCK AND THE DUMMY LEADER
2700 IND1=0
2701 READ(5,2702) IT1, IACT
      READ(5,2702) NSUBI
      READ(5,6600) (NSUB(I), I=1, NSUBI)
6600 FORMAT(10I4)
C      NSUB IS THE NUMBER OF RECORDS TO BE PROCESSED FOR FINER ALTITUDE
C      TREATMENT FOR TOTAL PARTICLE NUMBER
      IS65=1
      ISJ98=0

```

```

IRECIN=IRECNO+1
IRECFN=IRECIN+NSUB(1565)
I98=NSUB(1565)
I570=0
QSJM=0.0
IPRT=0
2702 FORMAT(2I4)
2703 CONTINUE
READ(15,700,END=198,ERR=112) JDATA
IRECNO=IRECNO+1
700 FORMAT(6(255A2),230A2)
IND1=IND1+1
I570=I570+1
2003 FORMAT(1H,20I6)
IF(IACT)2704,2705,2705
2704 IF(IND1-IT1)2703,2700,2700
2705 CONTINUE

```

```

WRITE(6,2912)(JDATA(I),I=1,48)
2912 FORMAT(8I10)
DO 3000 I=1,1760
IF(JDATA(I))3001,3002,3002
3002 KDATA(I)=JDATA(I)
GO TO 3000
3001 KDATA(I)=JDATA(I)+65536
3000 CONTINUE
GO TO 141
198 WRITE(6,2004)
2004 FORMAT(24H END OF FILE , IRECNO = )
WRITE(6,2003) IRECNO
IRECNO=IRECNO+1
I570=I570+1
IND1=IND1+1
IF(IACT)2707,2708,2708
2707 IF(IND1-IT1) 2703,2700,2700
2708 IF(IND1-IT1) 2703,2706,2706
112 IRECNO=IRECNO+1
WRITE(6,1004)
1004 FORMAT(56H A TAPE ERROR IN RECORD HAS BEEN DETECTED, DATA IGNORED
1)
IND1=IND1+1
I570=I570+1
IF(IACT) 2709,2710,2710
2709 IF(IND1-IT1) 2703,2700,2700
2710 IF(IND1-IT1) 2703,2706,2706

```

```

141 J=1
DO 151 I=1,16
IH=KDATA(I)/256
IHOUSE(J)=IH
IH=KDATA(I)-IH*256
IHOUSE(J+1)=IH
J=J+2
151 CONTINUE
J=1
DO 161 I=17,1760
ID=KDATA(I)/256
IDATA(J)=ID
ID=KDATA(I)-ID*256
IDATA(J+1)=ID
J=J+2
161 CONTINUE
1005 FORMAT(6(E18.4))
CALL EVALJA(IRECNO,IHOUSE)
IF(IHOUSE(17)-46.) 7500,7501,7501
7500 I98=I98-1
IF(IND1-IT1) 2703,7502,7502
7502 GO TO 47
7501 CONTINUE
C SCALE THRESHOLDS TO ALLOW FOR LASED POWER
FACTOR=IHOUSE(19)/FLOAT(102)
Y10=FLOAT(ITRESR)
Y30=FLOAT(JTRESR)
X10T=CONVRT(Y10)*FACTOR
X30T=CONVRT(Y30)*FACTOR
Y10=(7.984375+ALOG10(X10T))/0.015625
Y30=(7.984375+ALOG10(X30T))/0.015625
ITRESH=Y10
JTRESH=Y30
WRITE(6,4008) ITRESH,JTRESH
4008 FORMAT(20H NEW 10 THRESHOLD = ,F10.4,20H NEW 30 THRESHOLD = ,F10.4

```

```

1)
44 ALITD=ALT
114 KOUNT=1
IIGN=0
KTR=1
KOUNTR=0
DATAR1=0.0
DATAR3=0.0
WRITE(6,920)
920 FORMAT(34H DATA HAS BEEN READ FROM THE DISK)
DO 51 I=1,91
BIN(I)=0.0
51 CONTINUE

```

```

C      CHECK FOR PARTICLES
      DO 21 I=1,3488*2
        IF(IDATA(I)-ITRESH)4000,23,23
      23 IF(IDATA(I+1)-JTRESH)4002,24,24
      4000 IF(IDATA(I+1)-JTRESH) 22,22,4001
      4001 IIGN=IIGN+1
        -GO TO 21
      4002 IF(IDATA(I)-ITRESH) 22,22,4003
      4003 IIGN=IIGN+1
        -GO TO 21
      24-IF(IDATA(I)-256.)25,20,20
      25-IF(IDATA(I+1)-256.) 26,20,20
      26 DATA(KOUNT)=CONVRT(IDATA(I))
        DATA(KOUNT+1)=CONVRT(IDATA(I+1))
        KOJNT=KOUNT+2
        -GO TO 20
      22-IF(IDATA(I).EQ.0.0) GO TO 20
        -IF(IDATA(I+1).EQ.0.0) GO TO 20
        DAR(KTR)=CONVRT(IDATA(I))
        DAR(KTR+1) = CONVRT(IDATA(I+1))
        DATAR1=DAR(KTR)+DATAR1
        DATAR3=DAR(KTR+1)+DATAR3
        KTR=KTR+2
        KOUNTR=KOUNTR+1
      21 CONTINUE
        IF(KOUNTR) 2000,2000,2001
      2000 DATAR1=0.0
        DATAR3=0.0
        RATIO2=0.0
        GO TO 2002
      2001 DATAR1=DATAR1/KOUNTR
        DATAR3=DATAR3/KOUNTR
        RATIO2=0.0
      2002 CONTINUE
        WRITE(6,4004) DATAR1,DATAR3
      4004 FORMAT(17H MEAN 10 BKGND = ,E15.8,17H MEAN 30 BKGND = ,E15.8)
        KOJMT=KOJNT-2
        KTR=KTR-2
        KKKT=KOUNT/2
        WRITE(6,4005) KKKT,KOUNTR,IIGN
      4005 FORMAT(28H PARTICLES IN THIS RECORD = ,I4,15H BKGND COUNT = ,I4,
        117H IGNORED PAIRS = ,I4)
C      CALCULATE STANDARD DEVIATION OF BACKGROUND
        SUM1=0.0
        SUM2=0.0
        DO 4215 I=1,KTR*2
          SUM1=SUM1+(DAR(I)-DATAR1)**2
          SUM2=SUM2+(DAR(I+1)-DATAR3)**2
      4215 CONTINUE

```

```

STAND1=SQRT(SUM1/KOUNTR)
STAND3=SQRT(SUM2/KOUNTR)
X10=ITRESH
X30=JTRESH
X1THC=CONVRT(X10)
XJTHC=CONVRT(X30)
WRITE(6,4006) X1THC,XJTHC
4006 FORMAT(26H CINVERTED 10 THRESHOLD = ,E15.8,26H CONVERTED 30 THRESH
10LD = ,E15.8)
WRITE(6,4007) STAND1,STAND3
4007 FORMAT(20H 10 BKGND STND DEV = ,E15.8,20H 30 BKGND STND DEV = ,E15.8
1)
C CALCULATE AND APPLY RAYLEIGH SCATTERING CORRECTION
WRITE(6,940)
940 FORMAT (32H FINISHED CHECKING FOR PARTICLES)
ICR=0
ICA=0
ICRA=0
ICAR=0
ICARI=0
DO 31 I=1,KOUNT,2
IFLGG=1
DATA(I)=DATA(I)-DATAR1
DATA(I+1)=DATA(I+1)-DATAR3
C CALCULATE THE RATIO AND SORT
ARATIO=DATA(I+1)/DATA(I)
DO 61 J=1,91
IF (ARATIO-RATIO(J)) 61,36,36
36 IF (J-30) 32,32,4018
32 CALL RECAL (DATA(I),AVG10)
DO 171 IJ=1,91
IF (DATA(I)-AVG10(IJ)) 172,172,171
172 J=IJ-1
IF (J) 31,31,315
315 IF (J-30) 4009,4009,416
4009 IF (IFLGG-1) 4011,4010,4011
4010 ICA=ICA+1
GO TO 37
4011 ICRA=ICRA+1
GO TO 37
416 IF (J-40) 4012,4012,4013
4012 WRITE(6,4014)J
4014 FORMAT(33H OVERLAP, PARTICLE COUNTED, J = ,I4)
IF (IFLGG-1) 4015,4016,4015
4016 ICAR=ICAR+1
GO TO 37
4015 ICRA=ICRA+1
GO TO 37
4013 WRITE(6,4017)J
4017 FORMAT(26H LRG OVERLAP, IGNORE, J = ,I4)
ICARI=ICARI+1
GO TO 31

```

```

171 CONTINUE
4018 CONTINUE
C SE IF AMPLITUDE IS LARGE ENOUGH
  SECCT=XITHC*10.0
  IF(DATA(I)-SECCT)4019,4019,4020
4019 IFLGG=0
  GO TO 32
4020 ICR=ICR+1
  GO TO 37
37 BIN(J)=BIN(J)+1.0

```

```

      GO TO 31
61 CONTINUE
  RATIO2=RATIO2+1.0
- 31 CONTINUE
  WRITE(6,950)
950 FORMAT(20H ALL DATA IS SORTED)
  WRITE(6,4021)
4021 FORMAT(31H FOR THIS RECORD THE COUNTS ARE)
  WRITE(6,4022)ICR
4022 FORMAT(34H PARTICLES FROM RATIO TEST ONLY = ,I4)
  WRITE(6,4023) ICA
4023 FORMAT(33H PARTICLES FROM ABS. CAL. ONLY = ,I4)
  WRITE(6,4024) ICAR
4024 FORMAT(38H PARTICLES MOVED FROM ABS. TO RATIO = ,I4)
  WRITE(6,4025)ICRA
4025 FORMAT(38H PARTICLES MOVED FROM RATIO TO ABS. = ,I4)
  WRITE(6,4026) ICARI
4026 FORMAT(30H TOO LARGE OVERLAPS, IGNORED = ,I4)
C CORRECT THE NUMBER OF COUNTS IN EACH BIN DUE TO INSTRUMENT
C DEAD TIME AND FLOW RATE
C CORRECTION DUE TO INSTRUMENT DEAD TIME IS
  IPRT=ICR+ICA+ICAR+ICRA
  COUNT=COUNT/2
  COUNT=1744.-COUNT
  CORINS=((16./11.)*1744.*ALOG(1744./COUNT)/(1744.-COUNT))
  QSUM=QSUM+FLOWAT(IPRT)/(FLOWRT*17.44)*CORINS
  IF(1570-NSJ3(1565))6500,6501,6501
6501 IF(198) 6790,6791,6790
6791 QSUM=0.0
  GO TO 6792
6790 QSUM=QSUM/FLOWAT(198)
6792 CONTINUE
  WRITE(6,6502) IRECIN,IRECFN,198
  WRITE(6,3581)QSUM
  QSUM=0.0

```



```

      IPRI=0.0
      I565=I565+1
      I570=0
      ISJ98=ISU98+I98
      IRECIN=IRECNO+1
      IRECFN=IRECIN+NSUB(I565)
6502 FORMAT(22H INITIAL RECORD NO. = ,I4,20H FINAL RECORD NO. = ,I4,20
      1 RECORDS INCLUDED = ,I4)
6500 CONTINUE
C      CORRECTION DUE TO FLOW RATE
      CORFLO=1./((FLOWRT*17.44)
      DO 41 I=1,91
      STORE(I) =BIN(I)*CORINS*CORFLO+STORE(I)
      41 CONTINUE
      STORE2=STORE2+RATIO2*CORINS*CORFLO
      IF(IND1-IT1)2703,2706,2706
2706 CONTINUE
      121 WRITE(6,930) IRECNO
      930 FORMAT (I10)
      47 CONTINUE
      43 WRITE(6,40)
      40 FORMAT (1#,///,40X,THE DISTRIBUTION OF PARTICLE SIZE IS,///,
      15(1# ALPHA NUMBER OF#)/,5(15X,PARTICLES#))
      ALPHA=.45
      DO 131 IJ=1,91
      ALPHA=ALPHA+.05

      IF(ISJ98)6794,6793,6794
6793 STORE(IJ)=0.0
      GO TO 6795
6794 STORE(IJ)=STORE(IJ)/FLOAT(ISU98)
6795 CONTINUE
      WRITE(6,50) ALPHA,STORE(IJ)
      50 FORMAT (5(F12.3,E12.3),/)
      131 CONTINUE
      IF(ISU98) 6796,6797,6796
6797 STORE2=0.0
      GO TO 6798
6796 STORE2=STORE2/FLOAT(ISU98)
6798 CONTINUE
      WRITE(6,90) STORE2
      90 FORMAT (/,# THE NUMBER OF PARTICLES DETECTED OF DIAMETER GREATER T
      HAN 1 MICRON IS,#E14.3)
3581 FORMAT(29H MEAN NO. OF PARTICLES/CC IS ,F8.4)
      LTITUD=ALTITD
      DO 3571 I=1,91
      STORE(I)=1000*STORE(I)
3571 CONTINUE
      CALL HIST(IRECNO,STORE,90)

```

```

      DO 3572 I=1,91
      IF(STORE(I)) 3572,3572,3573
3573 CONTINUE
      STORE(I)=ALOG(10.0*STORE(I))
3572 CONTINUE
      CALL HIST(I,RECNO,STORE,90)
      DO 111 I=1,91
      STORE(I)=0.0
111 CONTINUE
      STORE2=0.0
      GO TO 2700
45 CONTINUE
      STOP
      END
      SUBROUTINE EVALJA(I,RECNO,IHOUSE)

```

```

C
C   THIS PROGRAM CONVERTS THE HOUSEKEEPING DATA INTO THEIR PROPER UNITS
C

```

```

      REAL IHOUSE
      DIMENSION IHOUSE(32)
      COMMON      Z,FLOWRT,ALT,ALASER,PHOTO1,PHOTO2,HV,BATVOL,BATAMP,
      IELECTE,ALASTE,ALASC,VOLTL,VOLTH

```

```

C
C   THE VARIABLES REPRESENT THE FOLLOWING
C

```

C	FLOWRT = FLOW RATE	BATVOL = BATTERY VOLTAGE
C	ALT = ALTITUDE	BATAMP = BATTERY CURRENT
C	ALASER = LASER POWER	ELECTE = ELECTRONICS TEMP
C	PHOTO1 = TEMP OF PHOTOMULTIPLIER NO 1	ALASTE = LASER TEMP
C	PHOTO2 = TEMP OF PHOTOMULTIPLIER NO 2	ALASC = LASER CURRENT
C	HV = HIGH VOLTAGE	VOLTL = 0V REFERENCE
C		VOLTH = 5V REFERENCE

```

C
C   TEMP IS IN DEGREES ABSOLUTE
      WRITE(6,600) IHOUSE

```

```

600 FORMAT (6E20.3)
      IF(IHOUSE(20)) 5,5,6
      6 Z=(22.04+2.861*(5.*IHOUSE(20)/256.))
      5 IF(IHOUSE(17)) 15,15,16
      16 FV=5.0*IHOUSE(17)/256.

```

```

      FV2=FV*FV
      FLOWRT=-64.39+137.23*FV-5.686*FV2
      FLOWRT=FLOWRT/60.
15 IF(IHOUSE(18).EQ.0.0) GO TO 25
      ALT=(6.10*5.*IHOUSE(18)/256.)
25 IF(IHOUSE(19).EQ.0.0) GO TO 35
      ALASER=IHOUSE(19)*30./256.
35 IF(IHOUSE(21)) 45,45,46
46 PHOTO1=TR(IHOUSE(21))
45 IF(IHOUSE(22)) 55,55,56

```



```
WRITE(6,5)
WRITE(6,7)
```

```
C
C   FIND LARGEST FREQUENCY
C
      FMAX=0.0
      DO 20 I=1,IN
      IF(FREQ(I)-FMAX)20,20,15
15  FMAX=FREQ(I)
20  CONTINUE

C
C   SCALE IF NECESSARY
C
      JSCAL=1
      IF(FMAX-50.0)40,40,30
30  JSCAL=(FMAX+49.0)/50.0
      WRITE(6,1) <,JSCAL

C
C   CLEAR OUTPUT AREA TO BLANKS
C
40  DO 50 I=1,IN
50  JOJI(I)=NOTH

C
C   LOCATE FREQUENCIES IN EACH INTERVAL
C
      MAX=FMAX/FLOAT(JSCAL)
      DO 80 I=1,MAX
      X=MAX-(I-1)
      DO 70 J=1,IN
      IF(FREQ(J)/FLOAT(JSCAL)-X)70,60,60
60  JOJI(J)=K
70  CONTINUE
      IX=X*FLOAT(JSCAL)

C
C   PRINT LINE OF FREQUENCIES
C
80  WRITE(6,2) IX,(JOJI(J),J=1,IN)

C
C   GENERATE CONSTANTS
C
      JOJI(1)=1
      J=1
      DO 90 I=5,IN,5
      J=J+1
90  JOJI(J)=I
```

C
C
C

PRINT INTERVAL NUMBERS

WRITE(6,7)

WRITE(6,3) (JOUT(J),J=1,19)

WRITE(6,6)

RETURN

END

SUBROUTINE RECAL(DATA1,AVG10)

DIMENSION AVG10(91)

COMMON Z,FLOWRT,ALT,ALASER,PHOTO1,PHOTO2,HV,BATVOL,BATAMP,

IELECTE,ALASTE,ALASC,VOLTL,VOLTH

DATA1=DATA1*5.E+6*2.33/(ALASER/6.)

RETURN

END

FUNCTION TR(AB)

T=ALOG((256.-AB)/AB)

TR=298./(1.+0.0806*T)-273.

RETURN

END

0.581	10.9			
0.36199E-04	0.65344E-04	0.11231E-03	0.18520E-03	0.29476E-03
0.45491E-03	0.68327E-03	0.10017E-02	0.14370E-02	0.20212E-02
0.27919E-02	0.37934E-02	0.50764E-02	0.66994E-02	0.87296E-02
0.11244E-01	0.14334E-01	0.18105E-01	0.22683E-01	0.28219E-01
0.34889E-01	0.42901E-01	0.52491E-01	0.63912E-01	0.77425E-01
0.93270E-01	0.11164E 00	0.13265E 00	0.15632E 00	0.18258E 00
0.21132E 00	0.24242E 00	0.27590E 00	0.31190E 00	0.35082E 00
0.39327E 00	0.44010E 00	0.49234E 00	0.55118E 00	0.61788E 00
0.69371E 00	0.77976E 00	0.87680E 00	0.98500E 00	0.11038E 01
0.12318E 01	0.13668E 01	0.15065E 01	0.16486E 01	0.17919E 01
0.19362E 01	0.20824E 01	0.22329E 01	0.23908E 01	0.25600E 01
0.27446E 01	0.29493E 01	0.31782E 01	0.34348E 01	0.37207E 01
0.40346E 01	0.43718E 01	0.47240E 01	0.50806E 01	0.54309E 01
0.57670E 01	0.60856E 01	0.63882E 01	0.66803E 01	0.69704E 01
0.72683E 01	0.75844E 01	0.79296E 01	0.83144E 01	0.87484E 01
0.92381E 01	0.97841E 01	0.10378E 02	0.11001E 02	0.11624E 02
0.12215E 02	0.12749E 02	0.13213E 02	0.13610E 02	0.13952E 02
0.14261E 02	0.14557E 02	0.14863E 02	0.15202E 02	0.15596E 02
0.16065E 02				
0.85908E-04	0.15473E-03	0.26529E-03	0.43633E-03	0.69253E-03
0.10656E-02	0.15954E-02	0.23311E-02	0.33321E-02	0.46687E-02
0.64232E-02	0.86900E-02	0.11577E-01	0.15205E-01	0.19713E-01
0.25256E-01	0.32014E-01	0.40196E-01	0.50046E-01	0.61855E-01
0.75960E-01	0.92755E-01	0.11268E 00	0.13619E 00	0.16374E 00
0.19574E 00	0.23244E 00	0.27391E 00	0.31998E 00	0.37029E 00
0.42429E 00	0.48148E 00	0.54150E 00	0.60428E 00	0.67018E 00
0.73996E 00	0.81475E 00	0.89601E 00	0.98538E 00	0.10846E 01
0.11954E 01	0.13192E 01	0.14568E 01	0.16082E 01	0.17721E 01
0.19460E 01	0.21264E 01	0.23089E 01	0.24896E 01	0.26653E 01
0.28344E 01	0.29966E 01	0.31533E 01	0.33065E 01	0.34594E 01
0.36153E 01	0.37779E 01	0.39509E 01	0.41373E 01	0.43392E 01
0.45564E 01	0.47864E 01	0.50239E 01	0.52614E 01	0.54911E 01
0.57060E 01	0.59014E 01	0.60757E 01	0.62290E 01	0.63629E 01
0.64796E 01	0.65810E 01	0.66688E 01	0.67446E 01	0.68103E 01
0.68675E 01	0.69184E 01	0.69648E 01	0.70076E 01	0.70467E 01
0.70807E 01	0.71075E 01	0.71256E 01	0.71342E 01	0.71333E 01
0.71232E 01	0.71037E 01	0.70739E 01	0.70321E 01	0.69751E 01
0.68994E 01				
2000	53	38		
240	-1			
1				
240				
62	0			
2				
27	35			
61	0			
2				

36	25
40	0
2	
20	20
60	0
2	
35	25
33	0
2	
18	15
56	0
2	
31	25
60	0
2	
41	19
21	0
1	
21	
98	0
1	
98	
63	0
2	
30	33
53	0
2	
30	23
57	0
2	
30	27
62	0
2	
30	32
75	0
2	
40	35
82	0
2	
41	41
63	0
2	
30	33